United States
Department of
Agriculture

Agricultural
Research
Service

Northern
Plains Area

ARS CO-WY RESEARCH COUNCIL PROGRESS REPORT

1996

For Additional Information:

Dale F. Heermann, Research Leader
Water Management Research Unit
AERC-CSU
Fort Collins, CO 80523-1325

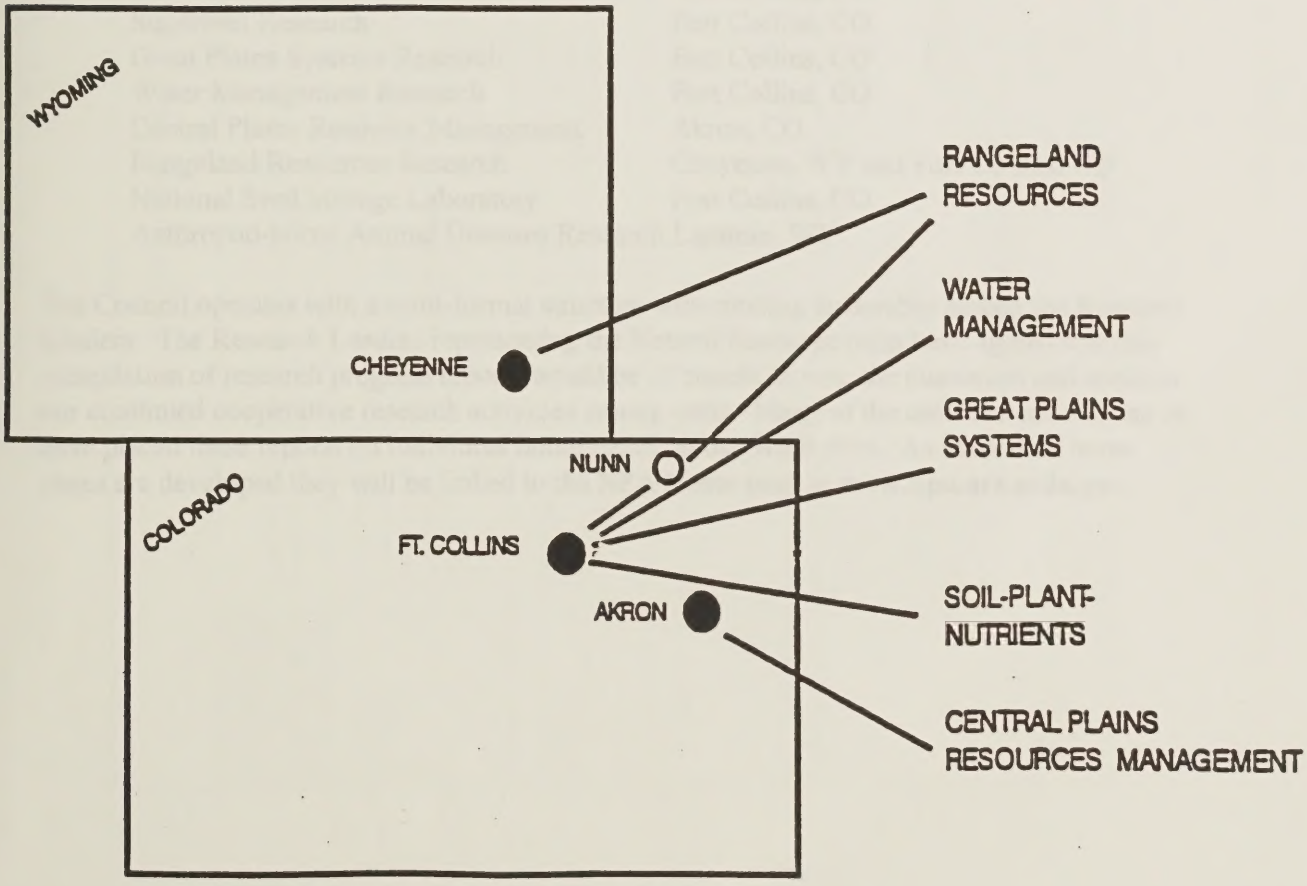
TEL: (970) 491-8229
FAX: (970) 491-8247

INTERNET: dale@lily.aerc.colostate.edu

USDA-ARS

NORTHERN PLAINS AREA

CO-WY RESEARCH COUNCIL



U.S. Department of Agriculture, Agricultural Research Service, Northern Plains Area, is an equal opportunity/affirmative action employer and all agency services are available without discrimination.

INTRODUCTION

CO-WY RESEARCH COUNCIL
Natural Resource Research Progress Report

Dale F. Heermann

The Natural Resource Research Leaders are continuing their partnering that was developed under the Natural Resource Research Center that was officially disbanded on July 1995. A Colorado-Wyoming Research Council was chartered by Will Blackburn, Area Director to promote and coordinate cooperative research activities among CO-WY Council research units; and facilitate communication and interaction with the NPA Director, and among research programs and units, and with customers locally, regionally, nationally and internationally.

The units include the administrative leaders for the following Colorado and Wyoming units:

Soil-Plant-Nutrient Research,	Fort Collins, CO
Sugarbeet Research	Fort Collins, CO
Great Plains Systems Research	Fort Collins, CO
Water Management Research	Fort Collins, CO
Central Plains Resource Management	Akron, CO
Rangeland Resources Research	Cheyenne, WY and Fort Collins, CO
National Seed Storage Laboratory	Fort Collins, CO
Anthropod-borne Animal Diseases Research	Laramie, WY

The Council operates with a semi-formal structure with rotating leadership among the Research Leaders. The Research Leaders representing the Natural Resource units have agreed that this compilation of research progress reports would be of benefit to you, the customers and assist in our continued cooperative research activities among units. Many of the units are considering or have placed these reports on individual home pages on our WEB sites. As individual home pages are developed they will be linked to the NPA Home page at **www.npa.ars.usda.gov**.

ARS CO-WY Research Council Staff - 1996

	Central Plains Resources Management Research	Great Plains Systems Research Unit	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Water Management Research Unit
Research Scientists	Randy Anderson,RL Joe Benjamin Rudy Bowman David Nielsen Merle Vigil	Lajpat Ahuja, RL Jim Ascough II Jon Hanson Gregory McMaster Marvin Shaffer Lori Wiles	Gerald Schuman, RL Terrance Booth Gary Frasier Richard Hart Jack Morgan	Ronald Follett, RL Jorge Delgado William Hunter Gordon Hutchinson Arvin Mosier Lynn Porter (Ret. 08-03-96)	Dale Heermann-RL Walter Bausch Gerald Buchleiter Harold Duke Edward Schweizer Roger Smith
Support Scientists	Curtis Reule	Patricia Bartling Mary Brodahl Gale Dunn Virginia Ferreira Harriet Havis	Daniel LeCain Jean Reeder Ernest Taylor	William O'Deen	Richard Miskimins Kristine Stahl Nancy Stevens
Post Docs	Robert Aiken	Rob Aiken Hamid Farahani Howard Skinner Chuanguo Xu Liwong Ma	Yuguang Bai		
Research Support Staff	Karen Couch Donna Diamond Michele Harms Albert Figueroa Bob Florian Donna Fritzler Linda Hardesty Stephanie Hill Cindy Johnson Delbert Koch Marrietta Koch Gene Uhler	William Dailey Debora Edmunds Robert Erskine Michael Murphy Daniel Palic Kenneth Rojas Lucretia Sherrod Bruce Vandenberg	Dean Ackerman Mary Ashby Leon Chea Stanley Clapp Pamela Freeman Larry Griffith Amy Lucero Chris Mahelona Matt Mortenson Dennis Mueller James Pry Jeffrey Thomas Barry Weaver	Charles Andre Edward Buenger Susan Crookall Anita Kear Cathy Krumwiede Robin Montenieri Elizabeth Pruessner Julie Roth Mary Smith David Wright	Douglass Barlin Ted Bernard Michael Blue Daryl Carr Margaret Herzog Hubert Lagae Dean Santistevan

	Central Plains Resources Management Research	Great Plains Systems Research Unit	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Water Management Research Unit
Administrative Support Staff	Ginger Allen Llewellyn Bass Carolyn Brandon Linda Pieper	Marcie Currie Gross Julie Leppert Marlene Miller	Ann Heckart Christine Parrish Kathleen Peterson	Stacey Wilkins	Marcie Currie-Gross	Maxine McCauley Lynnette VanGreuningen
Visiting Scientists/ Cooperative Staff	Mahdi Al Kaisi Scott Armstrong Mike Koch Manuel Rosales Josh Saunders Mike Sucik	Chad Bierbaum Stephen Canner Lois Deer-Ascough Sam Fernald Fritz Fiedler Hong Goa Melisssa Kraus Emily Li Michelle Palic Ben Riebau Huanxiang Ruan Karen Stonaker Howard Thompson Dave Wagner	Dennis Noyes	Lynn Porter, Ret. Mr. Sakorn Phongpan Dr. Pornpimol Chaiwanakupt		

PROGRESS REPORTS

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

Randy L. Anderson, Research Leader
Central Great Plains Research Station
40335 County Road GG
P.O. Box 400
Akron, CO 80720
TEL: (970) 345-2259
FAX: (970) 345-2088

E-MAIL: rlander@lamar.colostate.edu

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT
TABLE OF CONTENTS

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

CRIS PROJECT:

5407-12130-004-00 Dryland Cropping Systems to Improve Water and Nutrient Use Efficiency and Resource Protection

MISSION STATEMENT

To enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for maximum utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil conservation/preservation.

TECHNOLOGY TRANSFER - 1996

Central Plains Resources Management Research Unit

NRCS Soil Quality Team

1. Transferred ARS fact sheets to NRCS Northern Plains Region State Offices.

2. Designed, published, and distributed two fact sheets: 1) Before the CRP contract expires; and 2) Alternative Crop Rotations. The CRP fact sheet included a question/answer approach to create awareness of soil resource improvement due to CRP.

3. Presented information on Soil Quality and Cropping Systems to Soil Conservation Districts in Eastern Colorado.

4. Transferred soil quality data and technology from research institutions to Northern Plains producers.

ARS Staff:

1. Sponsored a Station Field Day on June 19, 1996. Approximately 200 producers, agricultural business representatives, USDA-NRCS personnel, and CSU scientists attended.

2. Interacted with the USDA-NRCS by serving on the NRCS research committee, and writing fact sheets that summarize our research data.

3. Served on the Board of Directors for the Colorado Conservation Tillage Association, and participated in their annual winter meeting.

4. Sponsored the Maximum Economic Yield (MEY) Club at Akron, where bi-monthly meetings are held each winter. Staff presented their research data to producers.

5. Cooperated with the Eastern Colorado Range Station by guiding their cropping systems decisions and integrating cropping with livestock production. Presented cropping systems data at their annual winter meeting.

6. Hosted tours composed of foreign visitors, explaining our cropping systems and research studies.

7. Presented research data at the Great Plains Fertility Conference, NRCS field days, the Southern Plains CRP Conference, Sidney, NE Research Station field day, and the National Sunflower Association Winter Workshop.

COMPACTION STUDY

Soil Quality Team: Manuel Rosales, Mike Sucik, Josh Saunders;
Mike Petersen[1], and Jim Lengel.[2]

PROBLEM: Soil Compaction is a serious problem, directly related to land preparation, tillage and particularly to harvest operations. According to University of Nebraska, Cooperative Extension Service publication (NebGuide-G87-831) compaction can cause yield reductions up to 60 percent. In an effort to alleviate compaction problems observed in irrigated cropland in Eastern Colorado, the Irrigation Research Foundation at Yuma County, Colorado, and USDA- Natural Resources Conservation Services set up a demonstrational compaction study to determine which implements, chemicals or management practices have potential to aid area producers in reducing soil compaction.

APPROACH: The study consisted of nine treatments, 5 subsoilers, 2 chemicals, induced compaction plot and control: 1) spring rip slagel (rip and plant); 2) inter-row rip #1 dammer-diker; 3) inter-row rip #2, blue jet; 4) inter-row rip #3, acra plant with alamar diker; 5) acra plant; 6) corn sol; 7) super-bio-plus; 8) induced compaction (done by driving a manure truck weighing about 15 tons over the plot several times before planting); and 9) control (chisel, disc, plant). A compacted zone was detected at 12-15 inches. Bulk densities samples were taken before planting (April 27) and after inter-row-ripping (June 15). Soil samples were taken at the zone of compaction and subsoilers were to be placed at 22 inch depth (1.5 times the zone of compaction).

RESULTS: Bulk densities showed very small differences before and after treatment, except inter-row-ripper acra plant which decreased bulk density by 0.16 g/cc. A trench about 7 feet in depth X 3 feet wide X 180 feet long was opened with a back-hoe across all the plots to observe root patterns and effects of the rippers during the field day in August. Observations indicated that rippers did not reached the target depth zone (22 inches) to do a good job of shattering the compacted layer. During ripping soil was too moist and the ripper shanks knifed through the compacted layer instead of shattering it, consequentely the zone of compaction was left intact. Yields obtained at harvest (October 14) range from a low of 120 bushels/acre (@ 15.5% moisture) to a high of 150 bushels/acre for induced compaction and super- bio-plus, respectively.

FUTURE PLANS: The study will be conducted similarly for the next two years. A greater effort will be made to assure that rippers attain the proper depth, and ripping is done at an optimum moisture content. A plot amended with manure or crop rotation with a legume might be added to the study.

---

[1]Petersen: USDA-NRCS, Greeley, CO.

[2]Lengel: Irrigation Research Foundation, Yuma, CO.

RANGELAND HEALTH: A QUALITATIVE ASSESSMENT

Josh Saunders[3]

PROBLEM: Historically, rangeland planning provided by the NRCS, Natural Resources Conservation Service, was a process which concentrated primarily upon gathering vegetative data which would be used to determine range condition and range trend. This information was then reviewed with the land manager to ultimately determine suggested stocking rates and promote sound management decisions. Rangeland health is an ecological rating which evaluates the current functioning of the ecological processes on an ecological site. A rangeland health index provides the opportunity for the land manager and consultant to look beyond the classic range survey methodology and begin to monitor the ecological processes of the rangeland ecosystem.

APPROACH: A Rangeland Health Worksheet was developed by the NRCS Grazing Lands Technology Institute and their constituents. It was developed to assess the rangeland health of a site for NRI (National Resources Inventory). The assessment was made on Ascalon soil in MLRA-67. Key range sites were Sandy and Loamy Plains. Once the NRI point was located and the soil verified, a 300 foot transect was installed directly north of the NRI point. Flags were set every 30 feet. Flags (plots) 3, 6, & 9 were expanded to a 23.5 ft. diameter circle. The circle was alternated from right to left of the respective flags. The assessment within the circle was made by comparing ecological attributes: rills, water flow patterns, pedestals caused by erosion, gullies, bare ground, wind erosion, surface organic layer, infiltration capacity, cryptogamic crusts, functional plant groups, plant mortality, litter distribution; decay and amount, production, invasive plants, recruitment or reproduction, site resilience and site resistance to the historic rangeland site description support material. Observation of each attribute was ranked along a continuum of attribute descriptions from Class I which is the worst expected situation to the best situation, Class V.

RESULTS: The reason to evaluate rangeland health is to integrate the information provided by multiple attributes into a more comprehensive assessment of the ecological system. For instance, attributes such as litter distribution, decay, and amount, combined with other attributes, can be interpreted to tell something about nutrient cycling at the sample point. The health of an area of rangeland will be interpreted from the preponderance of evidence from all information recorded at the sample site. Seven sites were evaluated in the summer of 1996. The final results from the survey are being processed. This qualitative assessment provided good experience in giving thought to ecological processes and would be an excellent to training tool for agency and land managers. As with most subjective assessments, the written word may not always agree with actual infield observations.

FUTURE PLANS: Rangeland Health will continue to be evaluated in the future on private as well as public lands. Expect this model to be refined and localized for use.

---

[3] USDA-NRCS, Soil Quality Regional Technical Team

USING A NATURAL RESOURCES INVENTORY (NRI) TO MEASURE SOIL QUALITY

Soil Quality Team: Mike Sucik, Josh Saunders, Manuel Rosales

PROBLEM: Currently, the only way to measure the health of our nation's soils on a regional scale is by estimating erosion. Other factors such as soil fertility, infiltration rate, compaction, and biological activity have not been addressed by agencies evaluating the soil resource and can vary, even within the same soil type. By identifying and using management practices that increase organic matter, control compaction, and utilize more available water, it is believed that soil quality and productivity can be improved and sustained.

APPROACH: An area of the Central High Plains from Kit Carson County, Colorado to Goshen County, Wyoming was selected to collect samples of Ascalon soils. Ascalon soils are deep soils formed in sandy, wind-blown deposits. They typically have a sandy loam surface, a sandy clay loam subsoil and a sandy substratum. Ascalon soils are used for dryland cropping, irrigated cropping, pasture, range, and CRP among other land uses. The points sampled are part of a Natural Resources Inventory that has monitored land use since 1977. Three other areas throughout the U.S. were also selected to measure soil quality on other soils.

Soils were sampled for Total C, CaCO3, Total N, CEC, Aggregate Stability, pH, Phosphorus, Potassium, Potentially Mineralizable N, Microbial Biomass, Organic Matter, Bulk Density, and other analyses. Samples were collected from 0 to 3 cm and 3 to 10 cm depths at each location. they were collected during a six week period from late June to early August. Range health was evaluated at native grass sites.

RESULTS: Lab analyses have not yet been completed on the soil samples. After samples have been analyzed, results will be compared to land use and management practices to evaluate the effect of different practices on soil quality. Climatic factors will also be taken into consideration. It is hoped that the results can tell us which land management systems are most likely to improve and maintain soil quality for sustainable agricultural production.

The data collected will also be recorded and compared to previously collected samples of Ascalon soils. Some of this information will also be able to be used to evaluate the effects of management on other soils that are in some ways similar to Ascalon.

FUTURE PLANS: Tentative plans are for two eastern regions of the U.S. to be sampled for soil quality during the 1997 NRI. The Forest Service and BLM are in the process of developing a plan to sample soil quality and range health on public lands in 1997 using a similar procedure to which we used in 1996. The 1996 data will be analyzed and recommendations will be made as to which measurements are critical to assessing soil quality in future studies. Ideally, we will resample the points we sampled in 1996 again in about five years to try and determine whether the soil resource is maintaining a desired level of quality.

FIELD DECOMPOSITION RATES AND SOIL COVER OF SURFACE CROP RESIDUES

Aiken, R.M., M. Vigil, G. Uhler, M. Shaffer[1]

PROBLEM: Surface crop residues reduce soil erosion and can improve soil water storage, conditioning the biological environment of crop seedlings and associated pests. Decomposition of surface residues alter these benefits and biological risks, and may compromise conservation compliance of dryland cropping systems. Knowledge of environmental factors altering decomposition rates can guide surface residue management.

APPROACH: Seasonal decomposition rates of surface crop residues (wheat, millet and corn) were measured under field conditions using litter bags, screen shelters and grab samples, collected at 1000 degree day intervals. Changes in biochemical composition of residues were sampled at initial, mid and final stages of field exposure. Accumulation of surface crop residues in various wheat, corn and millet crop sequences of the Alternative Crop Rotation study was determined pre-plant and post-harvest over four crop seasons. We quantify daily temperature effects on decomposition rates using a first order rate model, scaled to thermal time (cumulative degree days).

RESULTS: Field sampling was completed and sample processing is near completion for controlled residue placement. Dry surface conditions and high carbon:nitrogen ratios resulted in similar decomposition rates among dryland grain crops. First order rate constants, scaled to thermal time, appear consistent for lab and field data available for wheat, corn and millet residues. The half-life of standing plus surface residues appears to be 5800 °C day, about 1.5 years of calendar time, while a shorter half-life for surface residues under wet soil conditions indicates more rapid decomposition.

FUTURE PLANS: Processed residue samples will be submitted for biochemical analysis. We'll evaluate relationships among diagnostic residue attributes and environmental factors altering decomposition rates and soil cover. Manuscript reporting results will be submitted for publication, subject to peer review.

---

[1]Great Plains Systems Research

SEASONAL RESIDUE IMPACTS ON RADIATIVE AND CONVECTIVE EXCHANGE PROCESSES

Aiken, R.M., D. Nielsen, L.R. Ahuja[1]

PROBLEM: The distribution of standing and flat surface crop residues condition the habitat of crop seedlings and associated pests. Cooler and wetter soils, associated with no-till crop management, alter decomposition rates of surface residues as well as soil quality factors impacting water management. Knowledge of residue effects on surface microclimate and subsequent processes can guide soil and water management.

APPROACH: We installed radiation, temperature, wind and soil water sensors in 10 m x 30 m plots of standing wheat, millet, corn and sunflower residues following harvest. Hourly data acquisition was screened for sensor reliability prior to archiving for subsequent analysis. Sheltering and insulating effects of crop residues are quantified as solar reflectance and wind velocity at 0.2 m relative to reference wind speeds at 2.0 m. Cover of flat residues and persistence of standing stems were sampled periodically. An energy balance simulation module of the Root Zone Water Quality Model quantified residue effects on evaporative demand.

RESULTS: Data acquisition is completed for fallow periods through pre-plant tillage for wheat, millet, corn and sunflower residue. Preliminary data analysis indicates soil-crop residue systems differ in absorbed solar radiation, in relative windspeed at 0.2 m, and in near surface temperature dynamics. Simulation results indicate the shading and insulating effects of crop residues can reduce potential evaporation by 30 to 70%, relative to bare soil, under wet soil conditions.

FUTURE PLANS: Data analysis will identify relationships among residue attributes (reflectance, silhouette factor, etc.), and exchange processes (radiation, convection). Data will provide independent evaluation of energy balance modules of the Root Zone Water Quality Model for winter and non-freezing conditions. Manuscripts reporting results will be submitted for publication, subject to peer review.

[1]Great Plains Systems Research

STRUCTURAL COMPONENTS OF STEM STRENGTH FOR WHEAT CULTIVARS

Aiken, R.M., M. Vigil, G. Dunn[1], J. Shanahan[2]

PROBLEM: Standing crop residues insulate the soil from erosive and evaporative winds in semi-arid climates. These benefits decline as strong winds blow over decaying residues. Variation in stem strength alter susceptibility of crop cultivars to lodging as well. Rapid quantitative screening tools indicating stem persistence can enhance selection of superior cultivars.

APPROACH: Quantitative measures of stem strength provide tools for evaluating cultivar susceptibility to lodging and standing stem persistence. We used the cantilever principle to measure structural components of stem strength (shape factors and intrinsic strength) for the upper three internodes of nine wheat cultivars. We also determine biochemical properties of internode segments.

RESULTS: Stem measurements and data collection are completed. Preliminary analysis indicate the intrinsic strength of wheat stems is similar to that of wood. Variation in stem strength among wheat cultivars appears to result from diameter and thickness of stem walls. Rapid and inexpensive stem strength measurements could be incorporated in varietal selection programs.

FUTURE PLANS: We will test for significant differences in stem strength among the selected cultivars. Also, we'll evaluate the relationships of stem strength components with biochemical fiber analysis and field lodging observations of the selected cultivars. Manuscript reporting results will be submitted for publication, subject to peer review.

---

[1]Great Plains Systems Research, [2]Colorado State University

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT - FALLOW

R.A. Bowman, M.F. Vigil, J.B. Benjamin, D.C. Nielsen, R. M. Aiken, and R.L. Anderson

PROBLEM: Producers in the Central Great Plains rotate winter wheat with fallow. Fallowing degrades soil by increasing loss of organic matter and organic nitrogen while exposing soil to wind and water erosion. Producers can counter this trend in soil degradation by cropping more frequently. Producers in semiarid regions rely on fallow to stabilize their crop production. However, improved weed control methods during non-crop periods have increased precipitation storage efficiency, thus producers have more available soil water for crop growth. Also, new crop varieties are more efficient in converting water into grain, thus the need for fallow may be less than historically perceived.
This study is evaluating crop rotations to increase cropping intensity and subsequently, reduce the amount of fallow.

APPROACH: A crop rotation study with 18 rotations was initiated in 1990 on a Weld silt loam at the Central Great Plains Research Station. Crops include: winter wheat, corn, sunflower, proso millet, foxtail millet, field pea, black turtle bean, triticales, and oat for hay. With all rotations, we are minimizing tillage. Tillage is required to incorporate herbicides for sunflower. Three tillage systems, conventional-, reduced-, and no-till, are included in the wheat - fallow rotation as a basis for comparison in soil quality changes. Standard agronomic practices for seeding rates, planting dates, varieties, and weed control are being followed.

RESULTS: During 1994-1996, W-C-M was the highest yielding rotation, yielding 90% more grain on a land area basis than W-F. We are exploring factors in the soil system that may explain why continuous cropping continues to improve compared to wheat-fallow. Factors include: mycorhiza populations as affected by previous crop, soil organic matter buildup, precipitation infiltration, and intensity of root diseases. Identifying the causes of this rotational improvement will supply guidelines for producers to maximize its effect in cropping sequences.

Corn yields were the highest since the study begin, with yields approaching 80 bu/ac. Precipitation during the summer of 1996 was very favorable: rain occurred every 7 to 10 days. Whenever corn followed winter wheat, yields were high; corn after black turtle beans, proso millet or foxtail millet yielded less. Proso yields were also the highest recorded in the history of the study.

Sunflower was infested with phoma, a soil-borne fungus. This disease led to severe lodging, especially with the M-S and W-S-F rotations. Control of this disease requires that sunflower be grown in the rotation only once every four years. Sunflower in W-C-S-F and W-M-S-F rotations did not lodge and yielded > 1600 lbs/acre, twice the yield of W-S-F.

FUTURE PLANS: We are converting unsuccessful rotations into two new rotations: 1) W-C-M-Green Fallow, (to examine the effect of a legume-based fallow in an extended rotation); and 2) W-W-C-M.

INTEGRATING CROPPING SYSTEMS WITH LIVESTOCK SYSTEMS

D. Schutz[1] and R. Anderson

PROBLEM: The Central Great Plains Resource Management Research Unit is exploring alternative cropping rotations, with the goal to increase cropping intensity and consequently, cropping diversity. The CSU Eastern Colorado Research Center (ECRC) at Akron (Range Station) is exploring alternative feeds for effect on weight gain and overwintering of livestock. Inclusion of livestock in the overall production system not only increases potential use and markets for alternative crops, but also serves as drought insurance (poor grain crops could be turned into forage). The purpose of this team effort is to implement alternative cropping systems at ECRC for better utilization of crop aftermath and alternative forages while reducing annual cow costs.

APPROACH: Studies are evaluating harvest efficiency of cattle grazing foxtail millet in swaths versus baling and feeding hay. Cattle were placed on the experimental site during the month of November, with daily weight gain and body condition score change being calculated. A second study is testing triticales for early spring grazing as an alternative feed source for cattle production.

We also are evaluating intercropping corn and sunflowers for silage quality. Corn and sunflower were planted alone and in alternating rows. Planting date was May 18, with Prowl applied without incorporation for weed control. The studies are conducted at both the ECRC station and the Central Great Plains Research Station.

RESULTS: Producers can extend their winter range feed supply by growing foxtail millet and triticales. Triticales was grazed for 45 days in the spring, yet grain yields were not detrimentally affected. Triticales begins spring growth earlier than either the winter range or winter wheat, and supplies high protein forage before the range grasses initiate growth. Cattle weight gain is greater when triticales is included compared to winter range alone. Fall harvesting of foxtail millet extends the fall feeding season. The efficiency of cattle harvesting swaths remaining on the ground is sufficient to be more economical than baling and feeding cattle from a systems perspective.

Silage quality of sunflower is superior to corn, while tonnage is greater with corn. By intercropping corn and sunflower, producers can improve quality while still producing high tonnage of feed. A major obstacle is maintaining acceptable weed control within both crops. Currently, the only herbicide option is Prowl, which requires rainfall for incorporation. Lack of timely rainfall after Prowl application has led to poor performance.

FUTURE PLANS: We are implementing a study at the ECRC where we are comparing two systems: wheat - fallow versus triticales - foxtail millet - oat for hay. The forage system will be integrated with the cow-calf herd maintained on the ECRC station. Our long-term objective is to develop integrated production systems for diversified farms, incorporating more intensive cropping with alternative cattle feeding programs.

---

[1]Dave Schutz, Eastern Colorado Range Station, Akron.

CROP HISTORY EFFECT ON WEED POPULATIONS IN SUMMER ANNUAL CROPS

R. L. Anderson

PROBLEM: Cropping patterns are changing in the Central Great Plains from wheat-fallow to more intensive crop rotations. One major contributing factor leading to this change in cropping is the replacement of tillage operations with herbicides for weed control.

However, public environmental concerns with the use of herbicides may limit or even eliminate future herbicide options. Secondly, several crops grown in this region do not have registered and effective herbicides for in-crop weed control. Because of these potential limitations, producers will need to use non-chemical weed control methods, including management practices that reduces weed seed production within the crop. Minimizing weed seed production in one crop may reduce weed populations in future crops, and subsequently reduce the need for herbicides.

The objectives of this study are: 1) determine the effect of cultural practices in winter wheat on weed populations in summer annual crops (oat for forage, corn, proso millet, and sunflower) planted the following year; and 2) rank crop response to wheat cultural systems in relation to weed population dynamics.

APPROACH: Three cultural systems are being compared: 1) Tam 107 at 675,000 seeds/acre planted in 12-inch rows, N at 60 lbs/ac applied in August before planting (conventional practices); 2) Lamar at 1 million seeds/ac planted in 12-inch rows, N applied in April before planting; and 3) Tam 107 at 1 million seeds/ac planted in 7-inch rows with N split applied: 45 lbs in April + 15 lbs with wheat seed at planting. Weeds during fallow after wheat harvest were controlled by tillage or herbicides, resulting in split plots. Oat, corn, proso millet, and sunflower were planted in the spring of 1996.

Summer annual weeds: redroot pigweed, kochia, Russian thistle, witchgrass, and green foxtail, were seeded at 200 seeds/m^2 in designated sites. Weed populations were recorded weekly for the first nine weeks of the crop growing season.

RESULTS: Weed populations were reduced 60% in corn, sunflower, or proso millet with system 2, with crops established in no-till. By tilling the soil, weed emergence was increased 20 to 25%. The major weed in all crops was green foxtail. Weed biomass was greatest in corn.

With oat, the predominate weeds were downy brome and volunteer wheat. We planted the oat in mid-March, which may have been too early for effective oat growth. Tilling the soil before oat planting increase grass weeds 10-fold. The major broadleaf weeds were kochia and Russian thistle, which were favored by no-till seed bed conditions.

FUTURE PLANS: This project is part of an overall systems project to develop weed management strategies that prioritize cultural practices before herbicides for weed control.

CULTURAL SYSTEMS FOR WEED CONTROL IN SUMMER ANNUAL CROPS

R. L. Anderson and D.L. Tanaka[1]

PROBLEM: Producers are seeking production practices that reduce pesticide use for economic and environmental reasons. Cultural practices, such as narrow rows and increased plant populations, may enable producers to enhance crop competitiveness to weeds. For example, by reducing row spacing from 76 to 38 cm and doubling the planting population of corn, producers can reduce herbicide use in the Eastern U.S. by 75% without reducing weed control. These cultural practices also may work with summer annual crops in the Central Great Plains.

Research with cultural practices usually focuses on the effect of one or two practices on weed control, but does not evaluate systems based on several cultural practices in combination. This study is examining the impact of cultural practice systems on weed growth and interference in proso millet and sunflower. The ultimate goal is to develop a cultural system that will eliminate the need for herbicides or if needed, will favor reduced rates of herbicides.

APPROACH: Proso millet. We are comparing the impact of tillage, N placement, seeding rate, and cultivar on growth and interference of redroot pigweed and green foxtail in proso. Weed emergence was recorded weekly during the growing season in designated m^2 sites. Placement of N involved time of application (April and before planting). Cultivars were Cope, a tall variety, and Sunup, a short variety, planted at two rates: 10 and 20 lbs/ac. Weed growth, and proso grain yields and biomass were determined.

Sunflower. Two systems were compared. The conventional system consisted of sunflower planted in 30-inch rows at 16,000 plants/acre on June 5. Herbicide and insecticide were applied for pest control. The second system, relying on cultural practices only, consisted of sunflower planted June 20 at 23,000 plants/acre in 15-inch rows. No pesticides were applied in this system.

RESULTS: Proso millet. Weed emergence was increased 41% by tillage. Weed biomass was reduced 56% by growing Cope at 20 lbs/ac seeding rate. Cope yielded 20% less than Sunup, which contrasts with 1995, where Cope yielded 16% more than Sunup. Nitrogen placement was not effective in minimizing weed growth.

Sunflower. Weed biomass was reduced 90% in the cultural system compared to the conventional system. Seed yield and oil content did not differ between systems. The favorable precipitation in 1997 may have masked the planting delay yield penalty that frequently occurs with sunflower.

FUTURE PLANS: Cultural systems in proso will compare Huntsman (a new tall variety) with high seeding rate and narrow rows to the conventional system with Sunup. The sunflower study will be repeated.

---

[1]Tanaka: USDA-ARS, Mandan ND.

WILD BUCKWHEAT ECOLOGY AND INTERFERENCE IN WINTER WHEAT

R.L. Anderson

PROBLEM: Wild buckwheat is a prevalent weed in the Central Great Plains, and may reduce yields in wheat or proso millet. Herbicide options exist for wild buckwheat, but environmental concerns have stimulated a more balanced approach to weed control, where cultural practices are incorporated with herbicide options into management systems. Developing effective integrated management systems for specific weed species requires knowledge about ecological characteristics such as time of seedling emergence, rate of seedling development, and peak growth periods. This study is characterizing wild buckwheat's ecological characteristics and developing a yield loss equation based on wild buckwheat populations in winter wheat.

APPROACH: Emergence pattern was determined by counting weekly seedling emergence form five 1-m^{-2} sites. Ten seedlings of wild buckwheat were established in winter wheat starting on April 1 and weekly until May 5. Development was monitored weekly, and biomass and seed production measured at winter wheat harvest.

To determine wild buckwheat rooting depth , winter wheat (Tam 107) and wild buckwheat were planted in the following sequence: Tam 107 alone, wild buckwheat alone, Tam 107 + wild buckwheat, and a control of no plants. Neutron probe readings, from access tubes placed in the center of each plot, were taken weekly, starting on April 1.

Wild buckwheat was established at: 5, 10, 25, 50, 100, and 200 plants/m^{-2}, into Tam 107 (planted at 45 kg/ha). Plots were split, with a control included for each population. Yield loss equations based on infested populations were examined.

RESULTS: Wild buckwheat emergence has been recorded over three years, with emergence varying considerably among years. Peak emergence (> 90% of total emergence) occurred between April 28 and May 12 in 1993, April 7 and May 16 in 1994, May 20 and June 14, 1995, and May 14 and June 26, 1996. Daily air temperature averages were similar for initiation of emergence among all years: daily maximum averaging 62.4 F for the seven days preceding emergence, and daily minimum being 35.2 F. Plants established with pellets did not survive in either 1995 or 1996. Because of late emergence in both 1995 and 1996, wild buckwheat interference did not reduce winter wheat yields. Wild buckwheat rooting depth was shallow, indicating that nitrogen placement deep in the soil profile will favor winter wheat over wild buckwheat.

Wild buckwheat will not be a serious weed in winter wheat, due to its late emergence in the spring. However, it causes large yield losses in proso millet. Emergence data will guide herbicide applications (such as Ally) within winter wheat to ensure that wild buckwheat does not survive and produce seed in the wheat canopy. This will reduce the soil seed bank population, and subsequently, reduce number of plants in proso millet seeded the next year.

FUTURE PLANS: We will establish wild buckwheat plants by planting seeds in the soil, and thinning back to selected populations. These plants will be monitored for growth and development.

PREDICTING SUNFLOWER STEM WEEVIL EMERGENCE ON THE CENTRAL GREAT PLAINS USING DEGREE-DAYS

J. Scott Armstrong & Mike D. Koch, Colorado State University, Department of Bioagricultural Sciences and Pest Management, Central Great Plains Research Station, Akron, CO

PROBLEM: The sunflower stem weevil (SSW) *Cylindrocopturus adspersus* (Leconte) infested dryland sunflowers on the Central Great Plains in economically devastating numbers during the 1994 season. Sixty to eighty percent preharvest lodging was common, resulting in several million dollars of unharvested sunflowers left on the soil surface. Adult sunflower stem weevils emerge in the spring (May to June) from one year old sunflower stalks, mate, and the female oviposits her eggs under the epidermis of the lower portion of sunflower main stem. Economic thresholds for the number of adult SSW per plant have been established, however, scouting for this insect is difficult because of its behavior of dropping off of the plant when disturbed. Any help in determining when SSW start to infest cultivated sunflowers would be of benefit.

APPROACH: This is the second year report of a three year study. The objectives are 1) to determine the life-stage diversity of the SSW from winter to spring, 2) determine if there is an accurate relationship of degree-days with first, 10, 50 and 90% emergence of the SSW. For 1995, six emergence cages enclosing ten SSW infested stalks were monitored at the Central Great Plains Research Station at Akron, CO. In 1996, emergence cages were placed at Akron, CO; Scottsbluff, NE; Colby, KS; Goodland, KS and Hays, KS. For further details of the methods used in this study, consult the 1995 Colorado State University Technical Bulletin LTB96-1.

RESULTS: In comparing SSW emergence for 1995 and 1996, it should be noted that the spring of 1995 was a record setting cool and wet spring, while the spring of 1996 could be considered very typical. Life-stage development of SSW was more advanced in 1996. This can be observed by comparing first emergence at Akron in 1995 with 1996. First emergence started eleven days earlier in 1996 compared with 1995 (Fig. 1). First emergence in the three Kansas sites occurred within nine days (Fig. 2). Average Degree-day accumulations averaged across all locations for first, 10, 50 and 90 % emergence were 329 ± 32, 369 ± 28, 475 ± 34, 581 ± 20 respectively (Table 1). It takes the female SSW about 10 to 14 days to mate and start laying eggs from the time of emergence. Management tactics for control the SSW should center around degree-days required for first emergence and the growth stage of the sunflowers. SSW in general will not infest sunflower plants until they reach six to eight leaves.

FINDINGS: Thus far in northeast Colorado, planting sunflowers after the 1st of June has been the most beneficial management practice for avoiding threatening SSW populations. In the comparison of using Calendar date versus relying on degree-day predictions for SSW emergence, both are accurate within the same year, however degree-day accumulations are more accurate for predicting SSW emergence among years. A general trend with this SSW emergence data shows the more southern locations accumulate degree-days faster, and SSW emergence starts a few days earlier. For example, SSW emergence started 22 days earlier in Colby compared to Scottsbluff in 1996 (Table 1.).

CROP ROTATION AND TILLAGE EFFECTS ON SOIL HYDRAULIC PROPERTIES

J. G. Benjamin

PROBLEM: Twenty million acres of non-irrigated land in the Great Plains are farmed with clean-till wheat-fallow (W-F) rotation. Studies at the Central Great Plains Research Station (CGPRS) at Akron, Colorado, have shown that inserting summer annual crops such as corn, millet, or sunflower into the rotation leads to a beneficial rotation effect where wheat yields increase with more years between wheat crops (W-F<W-C-F<W-C-S-F). The cause of these effects is unclear. Speculation has attributed the rotation effect to many biological and physical phenomena ranging from better water use efficiency to a more favorable microbiological population. Another cause for this effect could be an improved soil physical condition resulting from greater plant root activity (from the greater cropping intensity) or less destruction of soil structure and porosity (from the switch to fewer tillage operations). An improved soil physical condition could result in an increase of plant available water, less soil crusting, and better water infiltration. The objective of this study is to investigate changes in soil hydraulic properties, and subsequent changes in plant available water and water usage, caused by intensifying the crop rotation and decreasing tillage used for crop production.

APPROACH: An evaluation of soil hydraulic property changes caused by tillage and crop rotation was initiated in 1996. Samples were collected from the Alternative Crop Rotation (ACR) study at the Central Great Plains Research Station in Akron, CO. The rotations selected for study included: 1. wheat-fallow, conventional tillage (sweep plow 3 to 4 times during fallow); 2. wheat-fallow, no tillage; 2. wheat-corn-fallow, no tillage; 4. wheat-corn-sunflower-fallow, no tillage; and 5, wheat-corn-millet, no tillage. Field measurements of ponded infiltration rate, tension infiltration rates at -3 and -6 cm water head, and penetrometer resistance were taken in the fall of 1996. Soil cores were collected from the same plots for laboratory measurements of bulk density, saturated hydraulic conductivity, water diffusivity and water retention characteristics.

RESULTS: Preliminary results indicate the existence of a tillage or traffic pan at a depth of 40 to 50 cm under the sweep-plow tillage system. This traffic pan could possibly cause restrictions in root growth or limit plant available water. Analysis continues on bulk density, pore size distribution and hydraulic conductivity.

FUTURE PLANS: The experiment will be continued in 1997. Spring and fall samples will be collected to study the changes of soil hydraulic properties with time. Analysis of the observations should give indications of the effectiveness of the roots of different plant species for creating continuous pores and the subsequent effects on hydraulic conductivity and porosity.

METHOD DEVELOPMENT FOR EVALUATING AND QUANTIFYING SOIL QUALITY

R. A. Bowman and NRCS Soil Quality Team[1]

PROBLEM: In the semiarid areas of the Great Plains, continued clean-till wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of wind erosion and decomposition. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical, chemical and biological properties such as rooting depth, water storage and soil aggregation. Total pools of organic C in croplands are sometimes inadequate as predictors of trends in soil deterioration because they may lack sensitivity over the short term (1 to 3 years); but over the long term, this may not be the case. A need exists, therefore, to develop methodology to assess soil quality changes and direction of change. Our specific objective is to develop easy sensitive laboratory and field methods based on SOM content and other soil parameters to assess soil quality, and consequently, long-term soil productivity in croplands.

APPROACH: Our intent is to develop a quantitative index, which hopefully, will integrate losses in SOM due to erosion, decomposition, and nutrient uptake, and gains due to fertilization and net residue inputs and organic matter content from previous cropping. Besides measurement of SOM, labile organic C pools, enzyme activity, and other biologically based pools, bulk density (BD) and depth to lime (solum) are also measured. Thus, a Soil Quality Index (SQI) for new rotations other than wheat-fallow conventional-till is assessed based on SOM in the top 15 cm, the solum (kg organic carbon/m^2) or a predetermined depth (60 cm for cumulative organic mater index (COMI)). Additionally, a structural index (S_I) based on ratio of SOM % to clay % is also assessed to determine potential for degradation. Values for new crop rotations can then be compared to soils of the traditional wheat-fallow or with an adjacent native sod.

RESULTS: SOM concentrations at the 0-5 cm depths are important to reflect short-term changes (5-10 years) because of tillage and cropping intensities which may increase cover, but cumulative SOM content in the soil solum, or to a predetermined depth is more important to reflect the intrinsic productivity or soil quality of a site since this was acquired over many years. For instance, while the SOM content in the tillage depth may vary by less than 10%, the COMI for the Weld soil, Rago soil, and the Norka Colby soil is 6.8, 8.8, and 4.9, respectively. However, these values change significantly when expressed on a solum basis: 4.0 kg/m^2 for the Weld, 12.0 for the Rago, and 1.5 for the Norka-Colby because of the differences in solum depths of 0.50 m, 0.75 m, and 0.20 m, respectively.

FUTURE PLANS: The soil quality index will be evaluated on selected treatments within our cropping systems (WF, WCF, WCMF, WCM, WSunF, continuous cropping, grass/alfalfa), and our CRP sites. The surface depths (0-5 cm) will be used to assess accumulation of residue and litter carbon as expressed by the particulate organic matter (POM). Changes in the organic carbon in the silt and clay fraction will be used to show stabilization of new carbon from the residue. Three farmers sites per year will also be selected to assess soil quality field methods.

---

1. Mike Sucik, Manuel Rosales, and Josh Saunders.

SOIL ORGANIC MATTER DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

R. A. Bowman, M. F. Vigil, R. L. Anderson, D. C. Nielsen, and J. Benjamin

PROBLEM: Soil organic matter is important to hold the soil together, to easily infiltrate water, to reduce compaction, and to provide nutrients such as N, P, K, S, and micronutrients. However, the conversion of Great Plains grassland to clean-till small grain farmlands since the mid 19th century has resulted in extensive loss of the native SOM because of wind erosion and decomposition. On a global basis,with about 40% more organic carbon residing in the SOM than in the terrestrial plant biomass, it is easy to see how the conversion of grassland to wheat-fallow could create over time a drop in crop production and a significant increase in global CO_2. On the other hand, if we intensify the cropping system over the WF, and minimize soil disturbance through less tillage, and if we manage water, fertilizer, and pests efficiently, we should be able to reverse SOM loss and increase soil productivity. Our objective, therefore, was to evaluate different cropping systems for their efficiency in water and nutrient use, minimal soil erosion, minimal chemical leaching, and organic matter buildup.

APPROACH: The study is located at Akron CO on a predominantly Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Anderson, Nielsen, Bowman, and Vigil for treatments). Extensive sampling was conducted on all 180 sites for soluble (dichromate oxidation) and total SOM, POM,and soluble organic carbon, total N (C N analyzer), and color absorbtivity at 550 nm of NaOH/EDTA extracts. Soil samples were collected at 0-5 cm (2 inches), and at 5-15 cm (4 inches) for stratification and for plow layer evaluations especially under the no-till conditions and mixing under conventional-till. Some measure of aggregate stability against wind erosion will also be assessed. Cumulative OM Index (COMI) and solum SOM will be assessed every 3 to 5 years.

RESULTS: Rotation plots were not assessed this year for COMI or solum SOM since it was believed that in this short time only the 0-5 and 0-15 cm depths would be influenced by residue and roots from rotation treatments. There was a significant increase in organic C (20%) from C in the POM for the WCM continuous treatments over WF treatments at the 0-5 cm depth. The soluble organic carbon also followed this trend where the lowest organic C was found with WF (428 ppm) treatments and the highest with WCM treatments (602 ppm). This soluble C is probably used by the microbes to degrade more resistant C from the residue. Since the plots were not broken out from native grassland, about 40% of the organic C was already lost compared to native sod. On a 15-cm basis, however, the C increases were not as large since very little C and N differences were found for the 5-15 cm depth.

FUTURE PLANS: Stabilization of new organic carbon from the residue and POM from different cropping intensities will be assessed by separating out the fines (clay and silt) from sand with POM. Lower depths will also be assessed for POM contribution from decomposing roots. A stability index (ratio of %SOM to %clay plus silt) will also be assesses since index this could indicate the degree of stability of the soil where erosion could present a problem.

P, ZN AND pH CHANGES UNDER ALTERNATE CROPPING SYSTEMS

R. A. Bowman and M. F. Vigil

PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (50 bushel dryland wheat requiring about 60 kg N and about 12 kg P, with 80 bushel dryland corn requiring about 80 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P, and S and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies. The objectives of the research, therefore, are to evaluate nutrient availability and cycling under WF and alternate cropping systems where more residue is returned to the soil surface, and consequently, more P recycled from within the soil profile. Information is needed for P, S, and Zn use efficiency for subsequent crops such as corn, millet, oilcrops or legumes after wheat in a reduced-till rotation.

APPROACH: In a Weld silt loam, various P parameters were measured at the 0-5 and 5-15 cm depths to assess P availability and cycling in selected plots from our alternate cropping and tillage system study (ACR). These parameters included available P pools such as those extracted by bicarbonate and anion-exchange resins, total soil P, and total soil organic P, residual P and phosphatase activity which is a measure of quickly available organic P. Available S and Zn were also evaluated in the surface 15 cm. Because of yearly N applications in continuous cropping systems, pH changes were also assessed. We also are assessing S levels because of our oil crops, and Zn because of corn.

RESULTS: As cropping intensity increased the amount of available inorganic and organic P increased, especially with the WCM rotation. Data clearly indicate more recycling of available P as we intensify the cropping system and produce more residue. Even though WF treatments received fertilizer P every second year and longer rotations less often (only the wheat phase is fertilized with P), continuous cropping rotations still contained more available surface P. As expected the grass and alfalfa treatments showed the highest total organic P content. This is the first year Zn has been applied to our corn crop, and results where half the plot received Zn and half didn't are not yet conclusive. Sulfur has not been applied to our oil crop plots in the ACR even though this could be warranted where SOM levels are less than 1.3% (some Rep 3 plots). Sulfur is studied independently in other field research by Vigil. Soil reaction (pH) is low with our continuous cropping rotations, but this does not seem to affect yields. We were able to see some symptoms of low pH in the greenhouse with low pH soils on the wheat main tiller, but this "bleaching" of leaves on the main tiller was not observed in the field.

FUTURE PLANS: We will continue to monitor nutrient data on ACR plots since we are only resupplying N and P. Role of residue in resupplying the others is important to monitor. Vigil is looking at P and S needs in proso millet and oilcrops.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

R. A. Bowman and R. L. Anderson

PROBLEM: Present Center projects relevant to CRP address soil and vegetation changes on small station plots. Hopefully, with other things being equal, these small plots will reflect the changes occurring in the over 30 million acres of highly erodible cropland set aside in grass for at least 10 years as part of the Food Security Act of 1985. A principal question in this billion-dollar experiment is whether the rested cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

APPROACH: Six farms in Washington County on the Conservation Reserve Program were selected from data obtained through SCS. Two went into the program in 1986, two in 1988, and two in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions: the original system (grassland or rangeland), the traditional farming system (winter wheat-fallow), and the CRP (regenerative system). We also studied the take-out of CRP lands under different grass control systems to recrop. Soil parameters measured included: SOM, POM soluble organic carbon, TKN, available P, and pH. Soils were sampled at 0-5 and 5-15 cm with a minimum of three field replications with five composites.

RESULTS: Previous data showed increases in SOM for the CRP sites compared to the conventional wheat-fallow. Generally, sod values were greater than both CRP and WF. Data showed a 0 to 10% increase in SOM for CRP sites over adjacent WF sites. Most of the increase came from the fine litter in the POM since fines (clay and silt without litter) recovered through screening from both sites did not vary significantly. There was about 5 percentage points more sand in the CRP sites than the WF sites, probably from more erosion in these more hilly CRP sites. CRP sites removed for cropping showed that grasses could be controlled with Roundup and one tillage without major loss in SOM gained over the rest period.

FUTURE PLANS: We will continue to evaluate data on soil SOM and nutrients on the 86, 88, and 90 sites. Physical properties such as texture, water infiltration, and soil aggregation will also be measured. We will evaluate also SOM changes on converting CRP lands back to a wheat-based cropping system. We will be using no-till and reduced-till systems to preserve the gains attained during the 10-year period of CRP. We will be specifically looking to see which of these cropping systems will maintain the SOM acquired during the CRP rest period, and thus, the long-term productivity of that soil.

ORGANIC MATTER AND NUTRIENT CHANGES IN SIMULATED EROSION STUDIES

R. A. Bowman and M. F. Vigil

PROBLEM: Soil erosion is a serious problem in the Semiarid Plains. Its effects on water storage and nutrient availability have been extensively studied. Restoration with fertilizer or manures, and its effects over the long term are less well understood. Greb originally, and Smika later, conducted studies in the mid-50s with simulated erosion plots (different amounts of top soil removed) and added fertilizer. They removed from zero to 38 cm (15 inches) of top soil across the field. They were using added fertilizer to replace eroded topsoil in maintaining grain yields. We are presently revisiting these sites to evaluate long-term changes in selected chemical and physical properties (1956 vs 1996), and to assess presently, water use, crop yield and restoration potential of SOM with different N sources and sludge rates under more intensive and diverse cropping than the traditional wheat-fallow.

APPROACH: Nitrogen (ammonium nitrate), N and S (ammonium sulfate), and N, S, and micronutrients (sludge) were evaluated as they affected water use efficiency, and grain yields and residue production. Our first crop was sunflowers, but site was previously in proso millet and corn and wheat. These previous crops (corn and millet) were adversely affected by the high pH (free lime) eroded soils and both showed less growth as depth of top soil removed increased. We sample the soil profile for water and nitrates, and the top 15 cm for SOM, S, and Fe and Zn. We hope to introduce green manures and legumes to rebuild the SOM , and the production potential of the soil. Because of the differences in top soil removed, soil and plant data are assessed separately for these top soil removed increments.

RESULTS: Soil pH values were essentially neutral where no or very little top soil was removed (< 7.5 cm removed). Water uptake and yields were confounded by the lack of water use by the previous millet crop where top soil removed exceeded 22 cm (9 inches). Thus sunflower yields across the plots were not significantly affected by top soil removed. Data has just recently been collected and is still been evaluated.

FUTURE PLANS: Green manure will be incorporated in the rotations to increase SOM and improve soil physical properties. Role of added N, S, and micronutrients from sludge will continue to be evaluated.

WATER USE, YIELD AND AGRONOMIC PRODUCTION OF ALTERNATIVE CROPS UNDER AN IRRIGATION GRADIENT

David C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield.

APPROACH: Crops tested during the 1996 growing season were garbanzo beans (UC5, planted April 9), lentils (Brewer, planted April 9), pinto beans (Othello, planted June 5), and kenaf (Everglades 41, planted May 7, replanted June 10 due to hail). The plot area was under a solid set, gradient irrigation system. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses and the lowest level being rainfed with no supplemental irrigation. Soil water measurements were made with a neutron probe, with TDR used for the 0-30 cm layer. Water use was computed by the water balance method. One area of kenaf was cut for forage on Aug. 6, allowed to regrow, and harvested again on Sept. 26. A second area of kenaf grown for fiber grew from planting to Nov. 1.

RESULTS: Results for garbanzo beans and lentils are not very good for 1996 because of our poor management of the harvest. Neither were swathed in a timely manner, seed shattering occurred, and vegetative development and flowering continued. The rainfed plots of garbanzo beans were harvested on time, and the yield of 2689 lb/a for 16.0 inches of water use is reasonable. Much greater seed loss occurred in the lentils, so the yield of 428 lb/a for 16.6 inches of water use is not reasonable. Othello bean yields averaging 1500 lb/a for 12 inches of water use fit the same relationship as defined in 1995. There was no strong relationship between water use and forage production of kenaf, with yield averaging about 1500 lb/a (dry weight) for 10 inches of water use over 54 days of growth. There was very little regrowth during the 51 days following the first cutting. Average forage quality values were 22% crude protein, 78% dry matter digestibility, 45% NDF, and 29% ADF. Total fiber yield of kenaf averaged about 4500 lb/a (dry matter) for 24 inches of water use.

INTERPRETATION: No interpretation can be made of the garbanzo bean and lentil data. Othello bean may have a place in profitable dryland rotations. The quality of the kenaf forage is comparable to alfalfa hay, but perhaps slightly less palatable. The delayed kenaf planting date due to hail make productivity interpretations for both forage and fiber difficult.

FUTURE PLANS: The experiment will be repeated in 1997.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

D.C. Nielsen, R.L. Anderson, R.M. Aiken, M.F. Vigil, R.A. Bowman, and J. Benjamin

PROBLEM: Increased use of conservation tillage practices has made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Information is needed regarding water use patterns, rooting depth, water use/yield relationships, precipitation storage and use efficiencies, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains.

APPROACH: Six rotations [W-F(CT), W-C-F(RT), W-C-O(RT), W-SUN-F(RT), W-M-SUN-F(RT), W-SUN-M-PEA(RT)] are used for intensive measurements of water use and water stress effects on yield. (W:winter wheat, C:corn, F:fallow, M:proso millet, SUN:sunflower, PEA:pea CT:conventional till, RT:reduced till). Measurements include soil water content, plant height, leaf area index, grain yield, residue mass and cover, and precipitation.

RESULTS:

Rotation	Crop	ET (in)	Yield (lb/a)	Rotation	Crop	ET (in)	Yield (lb/a)
W-F(CT)	wheat	11.24	1642	W-C-O(RT)	corn	18.61	2752
W-C-F(RT)	wheat	9.89	3126	W-C-F(RT)	corn	17.26	4640
W-C-O(RT)	wheat	9.04	1256	W-SUN-F(RT)	sunflower	16.05	740
W-SUN-F(RT)	wheat	11.70	1970	W-M-SUN-F(RT)	sunflower	19.56	1564
W-M-SUN-F(RT)	wheat	14.69	3374	W-SUN-M-PEA(RT)	sunflower	17.81	1439
W-SUN-M-PEA(RT)	wheat	9.97	1338	W-M-SUN-F(RT)	millet	14.17	2285
W-SUN-M-PEA(RT)	pea	10.30	910	W-SUN-M-PEA(RT)	millet	11.17	1695

INTERPRETATION: Generally the crop yields vs. ET follow relationships previously established. An exception was sunflower in the W-SUN-F rotation which had 40% lodging due to an infestation of phoma. Approximately 3" more soil water is available to sunflower than to millet due to deeper rooting and soil water extraction to lower volumetric water contents by sunflower. Seventy percent of the variability of corn yields from year to year is explained by precipitation falling between July 15 and August 25 due to the critical water requirement of corn during flowering and early grain-filling.

FUTURE PLANS: Water use, yield, rooting depth, height, leaf area, and growth stage measurements will continue to be made for as long as these rotations exist.

DETERMINING BEST ADAPTED CULTIVARS AND OPTIMUM DRYLAND PLANT POPULATIONS FOR ALTERNATIVE CROPS

David C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. The objectives of this experiment were to determine best adapted cultivars and optimum plant populations for alternative crop species.

APPROACH: Potential adapted alternative crops are continuously being identified through contacts with other researchers conducting similar investigations in other areas of the country, and through literature review. During the 1996 growing season, four chickpea (garbanzo bean) cultivars (three kabuli and one desi type), and one lentil cultivar were evaluated, each at two seeding rates. The two seeding rates were higher and lower than recommended rates from other sources. Garbanzo bean and lentil were planted on April 24 with a row spacing of 10". Plots were swathed on July 23 or July 25, and samples were left to field dry. Samples were run through combine on August 8.

RESULTS:

Crop	Variety	Type	Population lbs/acre	Yield lb/acre
Chickpea	UC5	Kabuli	150	1190
Chickpea	UC5	Kabuli	75	982
Chickpea	UC27	Kabuli	125	1145
Chickpea	UC27	Kabuli	63	1215
Chickpea	Tammany	Kabuli	181	873
Chickpea	Tammany	Kabuli	91	867
Chickpea	Myles	Desi	75	1063
Chickpea	Myles	Desi	38	1243
Lentil	Brewer		158	617
Lentil	Brewer		79	775

INTERPRETATION: There was no significant effect of population on yield, but yields were significantly different between varieties. The lentils were the lowest yielding (695 lb/a), followed by Tammany (870 lb/a), UC5 (1086 lb/a), Myles (1153 lb/a), and UC27 (1180 lb/a). Rainfall during the growing period was 9.28". May, June, and July precipitation was 10.10", with the long-term average being 8.20". June 14 to July 6 precipitation (flowering and early grain-filling) was 3.43", so rainfall during this critical period of development was good.

FUTURE PLANS: The experiment will be conducted similarly next year. We have acquired some very small seed lots of lablab bean varieties which we will add to the experiment for evaluation and seed increase.

DRYLAND PRODUCTION OF RASPBERRIES WITH CROSS-LINKED POLYACRYLAMIDE (CLP) AND WEED/EVAPORATION BARRIERS

David C. Nielsen

PROBLEM: An alternative crop that may have potential as a cash crop in the central Great Plains is raspberries. The development and marketing of CLP, which has the ability to absorb and store large quantities of water, make the production of rainfed raspberries a possibility if sufficient water can be harvested from adjacent non-cropped areas and retained in CLP for later use by raspberry plants. A polypropylene weed barrier can enhance the benefit of natural precipitation by suppression of weeds and evaporation. Various bed construction factors, rates of CLP, types of weed barriers, catchment area to bed area ratios, longevity of weed barriers and CLP, rainfall/yield relationships, costs of production, and revenues from sales of product will need to be investigated.

APPROACH: Raspberry beds were established in May 1993 on a grassed rangeland area with approximately 3% slope (sloped to the SW). 1993 Progress Report gives bed details. A split plot, randomized complete block design (3 replications) with presence of weed barrier as main plots and 3 levels of CLP as subplots was established.

RESULTS: There was a major loss of raspberry plants noted in the spring of 1996. The loss appeared to be related to level of CLP. Nearly 75% of the plants in both the barrier and no barrier treatments for the 4 lb/plant CLP rate had died over winter. No plants were lost where there was no CLP present and the weed barrier was present. I decided to use some of the missing plot area to look at the effect of CLP and weed barrier on pumpkin and squash production. Although the pumpkin and squash plantings were not uniformly replicated, we can see a trend in the production data suggesting increased production of both pumpkins and squash with increased level of CLP and with the presence of weed barrier. Squash yields were more than doubled and pumpkin yields were more than tripled when moving from a CLP level of 1 lb/plant with no weed barrier to a CLP level of 4 lb/plant with the weed barrier. For reasons I can't explain, there was almost no raspberry production during 1996. Precipitation was above normal for the growing season, yet no mature raspberries appeared until 20 September, and then too few were produced to harvest.

INTERPRETATION: The severe loss of plants over the 1995-1996 winter may be the result of root damage to the raspberry plants during freeze-thaw cycles. The mechanical damage imposed on the roots may have been more severe where there was hydrated CLP. Perhaps annually planted crops, such as pumpkin and squash, would be better suited to production with CLP in environments which have many freeze-thaw cycles.

FUTURE PLANS: I will heavily mulch the remaining raspberry plants to see if that reduces winter kill. I will leave the 1996 canes on the plants to see if they will bear fruit early to avoid some of the hot, dry weather of the second fruiting period in August. I will try production of some other garden annuals, such as melons, in the areas where raspberries were lost.

TIMING OF WATER STRESS EFFECTS ON BLACK BEAN PRODUCTION

David C. Nielsen

PROBLEM: Black bean is a dry edible bean variety that may have potential for the central Great Plains, but little is unknown relative to the growth and production potential of black bean under the dryland growing conditions in this area. Unknowns associated with black bean production are how water stress at various growth stages affects growth, water use, rooting patterns, yield, and yield components. Knowledge regarding black bean sensitivity to water stress at various growth stages can help to determine if it will be suited for this environment.

APPROACH: Black bean (cv. Midnight) was grown in small plots that were covered by a rainout shelter during precipitation events. Three replications of four water treatments differing in timing of water application but not total amount applied were established. All plots received 7.25" of water over the growing season (the long-term average). Treatment 1 received equal weekly applications of water; Treatment 2 received no water during grain-filling; Treatment 3 received no water during flowering; Treatment 4 received no water during vegetative development. Evapotranspiration was calculated by the water balance method from neutron probe and TDR measurements of soil water content. Leaf area index (LAI) measurements were made with the LAI-2000 plant canopy analyzer.

RESULTS: Yields ranged from 2463 lb/a (TRT1) to 1679 lb/a (TRT3) in 1996. Stress during the reproductive stage reduced number of pods per plant. Water stress during grain-filling (TRT2) and reproductive stages reduced seed size. Evapotranspiration for TRT4, with stress during the vegetative growth stage, was lowest (10.4"), probably the result of lower leaf area development. Highest water use (13.9") was from TRT2 (stress during grain-filling). Soil profile water extraction ranged from 2.84" (TRT4) to 6.62" (TRT2). Soil water extraction in all four treatments occurred at all 6 measurement depths (down to 165 cm), indicating that these beans can extract water from fairly deep in the soil profile when the water is present.

INTERPRETATION: The significant reductions in bean yield with water stress during either the reproductive or grain-filling stage make production under dryland conditions somewhat risky. This experiment started with a full soil water profile. Under conditions of more limited soil water availability, yields could be unprofitably low. However. the yields from 1996 were 40% higher than the yields from 1995 because of the lower air temperatures and lower evaporative demand. The 1996 data suggest that black bean production may have a limited place in some farmers rotations, depending on adequate amounts of stored soil water and forecasts of a cool season with above normal precipitation.

FUTURE PLANS: This 1995 and 1996 data will be combined and written up for submission to Crop Science.

INFLUENCE OF LEGUME GREEN-MANURE ON WINTER WHEAT YIELDS

Merle F. Vigil, David Nielsen, and Rudy Bowman

PROBLEM: With the exception of water, nitrogen (N) nutrition is the most important limiting input to profitable winter wheat production in the central Great Plains. Increases in N fertilizer costs have caused some farmers to consider alternative systems that include legumes as a source of N. Farmers need to know how these systems impact winter wheat yields and economic returns.

APPROACH: Two sites have been established in which the main plots consist of legume species: Austrian winter peas, spring field pea (cv. Trapper), Indianhead lentils and a no-legume-summer-fallow plot fertilized at four N rates 0, 30, 60, and 90 lb N/ac. Within each main-plot, four sub strip plots are maintained which consist of four legume growth termination dates spaced two weeks apart. Soil water is measured in all legume plots and in the fallow plots at legume planting in April, at each legume-growth-termination event, at wheat planting and at wheat harvest to determine water used by the legume and the wheat. Above ground N and total legume biomass is determined at each termination date. Soil inorganic N is measured in each plot at each termination date in the top 2 feet of soil and at wheat planting time to monitor changes in available N. Following the legume fallow phase, wheat is planted and harvested using standard BMP's for dryland winter wheat.

RESULTS: We have three years of legume biomass data. Austrian Winter peas have been the overall best performer as measured by biomass production and total above ground N in plant tissue (between 1500-3000 lbs/acre). For the Austrian winter peas we calculated a water-use efficiency of 335 lbs of dry matter per inch of water used on June 13, 1994. The 335 lbs of biomass, contained 11.6 lb of N. In other words, 11.6 lbs of N was fixed or taken up by the legume for each inch of water use. The legumes used 5 inches of water (in addition to that amount lost in summer fallow) to produce 2400 lbs of dry matter. That 5 inches of water use has the potential of producing 25-30 bushels of wheat. We measured a 5 bu/acre reduction in wheat yield even at the earliest legume termination date of May 31. At current fertilizer costs legume N is too expensive to be considered a viable alternative. If one considers the additional value of the forage at a market price of $80/ton grown during fallow then the forage produced by the legumes (plus the reduced wheat yield) in this system is almost economically comparable to winter wheat fallow.

FUTURE PLANS: We are continuing the experiment for another three seasons. We will replace Indian Head lentils (which have not performed well at our location) with Hairy Vetch. Both hairy vetch and the Austrian winter peas will be fall seeded as opposed to spring seeded. We will replace the trapper field pea with Profee yellow pea to increase our knowledge of other potential legumes. We believe that 6 complete cycles of the system are needed to make a fair evaluation of potential changes in soil organic matter and mineralizable N. Much of the legume and wheat production information in this system will be ready for publication after this coming summer.

NITROGEN MINERALIZATION AND CROP RESPONSE TO MUNICIPAL SEWAGE SLUDGE

Merle F. Vigil and Rudy Bowman

PROBLEM: The disposal of municipal sewage sludge from large population centers is a national environmental concern. These materials, loaded with organic and inorganic nutrients, can be recycled in crop production systems as fertilizer and soil quality amendments. If managed properly, they become a resource instead of a waste product. However, the quantification of suitable rates of application, methods of application, crop response, and changes in soils after repeated application are data needed to adequately develop best management practices (BMP's) for these amendments.

APPROACH: The objectives of these experiments are to determine: (i) the amount and rate of decomposition of organic amendments (manures and sewage sludge) in farm soils, as fertilizer and as soil quality amendments for crop production. Field studies are used to compare the N response of dryland crops (canola in 1995, sunflower 1996) to 4 tons of dry granulated sewage sludge with the N response to 30, 60, and 90 lb/ac of N as ammonium nitrate in 4-rep randomized complete block field experiments.

Lab studies are being conducted to evaluate N and C mineralization amounts from these materials in Central Great Plains soils to developed first-order-decay-rate constants for dry-granulated sewage sludge. Simultaneously we are evaluating computer models for their ability to predict how these amendments will impact soil nutrient availability and crop uptake.

RESULTS: We measured a canola grain yield response to 4 tons/acre of dry-granulated sewage sludge (1100 lbs/acre) that was just slightly less than that found with 90 lb/acre commercial N (1490 lb/acre). Chemical fertilizer (ammonium nitrate) and sludge were applied 2 weeks prior to sunflower seeding on eroded plots in May of 1996. Because the sludge contained 5.3% N this field study suggests that during the growing season of early spring crops only 21% of the sludge N applied at planting will be available for crop uptake during the season.

We estimate from our lab studies that dry-granulated sewage sludge (5.3% N) applied at rates of 1.5 ton and 9 ton per acre will release (through microbial decomposition) 45 and 270 lbs of N in a given season under irrigated conditions in our region (about 28% of the total N applied). Under dryland conditions we may only see 34 to 200 lbs of N released for 1,5 and 9 tons of dry sludge. Less sludge N mineralization is expected on dryland because dryland soils are less biologically active then moist irrigated soils.

FUTURE PLANS: Sludge and manure studies are only in the beginning phases of research and will be continued. We are evaluating these products as an amendments to reclaim eroded soils.

WHEAT RESIDUE DECOMPOSITION AS EFFECTED BY HERBICIDE AND UAN APPLICATION UNDER FIELD CONDITIONS

Merle F. Vigil, R.L. Anderson and Rudy Bowman

PROBLEM: The amount and type of crop residues left on the soil after harvest affects soil erosion. For farmers to be in conservation compliance they must have, in accordance with their farm plan, a specified amount of residue cover at planting. Unfortunately, crop residues decompose after harvest and become less resilient during the non-cropped part of the season. These partially decomposed residues can then be wind blown and lost in the same manner as soil. Minimal quantitative information exists on the durability of standing crop residues as affected by the applications of herbicide and N fertilizer.

APPROACH: After wheat harvest (August of 1993, and 1994) 45 by 16 foot field plots were established with the following treatments where all rates are active ingredient/acre: 1) 0.5 lb Command + 0.5 lb Atrazine applied mid-August. 2) 0.5 lb Glyphosate + 0.25 lb Dicamba (Banvel) applications as needed. 3) 0.5 lb Paraquat + 1.0 lb Atrazine applied mid-August. 4) 0.5 lb Paraquat + 0.25 lb 2,4 D as needed. 5) no treatment, hand weeded (plastic spread over top of hand weeded area). 0.5 lb Command + 0.5 lb Atrazine. 6) tillage, no herbicide 2-3 times as needed (sweep plow with mulch treaders). Superimposed onto these treatments are three N regimes: no N applied, 30 lb N as UAN, and 60 lb N as UAN. All plots are replicated 3 times and arranged in a randomized complete block design. The following measurements are being taken. 1) Photo-documentation of plots was done after plots were established, after herbicide application, and then periodically as needed to document differences or lack of differences due to treatments. 2) The number of standing wheat stems is counted in select areas of each plot once a month during the no-snow months (depending on snow depth). Measurements continue until planting of the next wheat crop.

FINDINGS: This study has been completed. No increase in loss was measured from litter bag held residues or in standing stems from herbicide application after three years of measurement. Initially a color change is observed after herbicides and N solutions are applied. With time, color differences fade. The loss is primarily driven by the number of days with high winds, and optimal temperature and moisture for microbial activity. Herbicide treatments do not appear to have any direct effects on stem loss. Whereas, some indirect effects have been observed. We measured greater stem loss at the 60 lb N rate as compared to the 0 or 30 lb N rate. We found that the accumulated wind run was more highly correlated to the incremental loss of standing stem loss than either temperature or precipitation.

FUTURE PLANS: The experiment is complete and will be submitted for publication this winter.

NITROGEN RESPONSE OF CORN IN A DRYLAND ANNUAL CROPPING STUDY

Merle F. Vigil, Curt Ruele, and Ardell Halvorson

PROBLEM: Conservation tillage has increased annual soil water storage. This has enabled the use of annual cropping for some soils of the central Great Plains. Annual cropping entails greater biomass production which increases the need for more intensive N fertilizer management. This study is designed to evaluate long term changes in soil C and N under annually cropped dryland conditions under different N fertility. Short term, the study allows for the estimation of N use efficiency and fertilizer N requirements of various dryland crops.

APPROACH: This is the 13th year of the experiment, where under dryland conditions, the site has been cropped successfully with no fallow on a Weld silt loam soil. The site was in a barley-corn rotation until 1992 when oats for hay replaced spring barley. Winter wheat was grown in 1988 to replace a hailed out corn crop in 1987. Only one other year of the 13 year study has been a failure: in 1990 poor stand and aphids limited barley yields to 21 bu/acre. The experiment is a 4-rep randomized complete block where the only treatment is N fertilizer rates of 0, 20, 40, 60, 80 or 120 lbN/acre. The study is managed with no-till to conserve water and weed control has been through the use of contact and residual herbicides. Phosphorous (P) nutrition has not been limiting but low rates of P have been applied with the seed at planting or as broadcast treatments. Soil profile water and nitrates are monitored annually to determine N balance and water use efficiency.

RESULTS: Through the years, the optimum N rate for small grains has been between 40 and 60 lbs N /acre. For corn it has been between 60 and 80 lbs of N/acre. However, a buildup of excess nitrate-N can be found in the soil of plots fertilized at 80 lbs or more. This buildup is in excess of 300 lb/acre in plots fertilized at 120 lb N/acre. These results suggest that with this soil (under dryland conditions) annual fertilizer N rates can be excessive after 80lb/acre, on a long term basis.

Triticale yields in 1995 were 5.5 ton/acre at the optimum N rate of 80 lb/acre. On May 8, 1996, Corn was no-till seeded into stripped tilled triticale stubble. Volunteer triticale was sprayed with accent on June 3, and corn grain was harvested by combine on October 8, 1996. This year we had a difficult time establishing a good stand in the triticale stubble. Maximum grain yields of 90 bu/acre were measured at the 120 lb N rate. At the 80 lb N rate 75 bu/acre of grain was harvested.

FUTURE PLANS: We will continue this experiment for another 3 years to evaluate long term changes in soils under high N management and to determine changes in soil C and N with high productivity. We are considering the use of ^{15}N to evaluate fertilizer N recovery.

NITROGEN RESPONSE AND RESIDUE MANAGEMENT OF SUNFLOWERS IN A DRYLAND ROTATION

Merle F. Vigil, Rob Aiken and Rudy Bowman

PROBLEM: The current worldwide demand for edible oils has improved and somewhat stabilized the profitability of sunflowers in the Central Great Plains. However, knowledge of options for sunflower residue management and the fertilizer N response of this crop in the region is limited. Maintaining sunflower residues on the soil surface during fallow protects the soil from erosion, increases water infiltration and maximizes soil water storage. The objectives of these studies are: (i) to compare the loss of sunflower residues under no-till and reduce-till managed summer fallow, and (ii) to evaluate the nitrogen (N) use efficiency and plant derived N from fertilizer of this crop in a wheat-millet-sunflower-fallow rotation.

APPROACH: *In the sunflower residue study*: The disappearance of sunflower residue from sunflowers cut at two stalk heights (20 and 27 inches) were compared under no-till and reduce-till managed fallow in a 4-rep randomized complete block designed experiment. Weeds were controlled using a sweep-plow in the reduce-till plots. Glyphosate (Roundup) was used to control weeds in no-till plots. Standing-stem counts, percent-residue cover (line transect method) and surface-residue mass were measured during summer fallow on a monthly basis.

In the N fertilizer-rotation study: Sunflower were planted and fertilized in a randomized split-plot 4-rep experiment. Main plots consist of rotation crop/phase (sunflowers, proso-millet, wheat or fallow) and sub-plots are fertilizer N rates of 0, 30, 60, or 90 lbN/acre. All phases of the rotation appear every year in each replication. Soil water and inorganic N are monitored at planting and after harvest to assess water and N use efficiency and to evaluate deep N and water extraction by sunflowers. Individual plots are 60 ft by 240 ft in size. Deep placed ^{15}N labeled N will be used to evaluate fertilizer N recovery with soil depth.

RESULTS: Taller sunflowers (27 inch) fell over sooner then shorter sunflowers (20 inch). No-till resulted in 2950 lbs of residue mass per acre on the soil surface at wheat planting time and maintained greater then 35% residue cover during summer fallow. Sweep-plow managed fallow contained 1700 lbs of sunflower residue per acre at wheat planting time, but only 23% residue cover as measured by the line transect method. Sunflower N response was optimal at between 30 and 60 lb of N/acre. A visual N response could be seen at all N rates but this did not reslut in a yield response to all N rates. Much of the data collected in the N-response-rotation study is still being analyzed. We found that 80 % of the variability in sunflower residue mass could be described by a nonlinear function of the percent residue cover as measured by the line transect method.

FUTURE PLANS: For both studies only two years of data has been collected. The N response of sunflowers in a rotation requires at least 2 complete cycles of the rotation for long term conclusions. However much of the N response, and fertilizer N recovery information will be available after the first 3 years of the study.

SOIL CARBON AND NITROGEN CHANGES IN A LONG TERM TILLAGE STUDY

Merle F. Vigil, Curt Ruele, Randy Anderson, and Rudy Bowman

PROBLEM: Winter wheat-fallow is still the dominant cropping system in the Central Great Plains region of the United States. During fallow, weeds are generally controlled using sweep-plow tillage (stubble mulch). Weed control with herbicide chemistries currently available is generally too expensive to adopt unless a more intensive rotation is adopted. On the other hand, conventional tillage during fallow reduces soil organic matters levels at the soil surface and increases wind and water erosion.

APPROACH: This study was originally established in 1967 by Darryl Smika, modified by Ardell Halvorson in 1989, and modified again by Merle Vigil and Randy Anderson in 1996. In 1967 four weed control strategies during fallow were compared these were no-till (residual and contact herbicides only), reduce-till (residual herbicides in August after wheat harvest followed by tillage the next summer after residual herbicides had failed), stubble-mulch (sweep-plow managed summer fallow), and a moldboard plow treatment. This core set of plots has been kept since 1967. We have added a four year rotation of wheat-proso millet (or corn depending on weed and moisture conditions)-sunflower-summer fallow. This rotation was established to evaluate long term changes in soil Carbon and soil organic matter as influenced by intensive management. Other studies of an academic nature have included: a Delta ^{13}C dating of soil organic matter pools, studies to evaluate infiltration and compaction as influenced by long term tillage, and studies to evaluate fungal verses bacterial activity as influenced by tillage.

RESULTS: In general the no-till plots have not produced better than the tilled plots. The moldboard plow plots are less weedy then either the sweep tilled plots and/or the no-till or reduce till plots. The plots that have been exclusively in a wheat-fallow rotation are infested with jointed goat grass and cheat grass. Plots that have had a three year rotation of wheat-corn-fallow are relatively much cleaner with respect to weeds. Soil organic matter levels are being evaluated as a function of tillage and soil depth. The largest difference (as you might expect) is with lower surface organic matter levels in the moldboard plow treatment as compared with the no-till plots. Nearly 15 times more fungal activity is measured in the surface 15 cm of these soils then bacterial activity with no significant differences between tilled and no-till plots..

FUTURE PLANS: We are looking for ways to reduce grassy weed pressure through methods other than rotation. New in-crop herbicide chemistries will be tried (Liberty, Accent) combined with late planting of a tall variety where a burndown herbicide is used just prior to planting. Because of its long term history the experiment has become valuable for looking at long term changes in soil organic matter, total soil N and C and changes in soil tilth at the soil surface. The experiment has been identified as a unique part of a network of long term experimental sites across the United States and Canada. Long term changes in soil surface C and soil tilth is being evaluated across that site network. We would like to keep the experiment going for 8 years in order to complete 2 cycles of the four year rotation.

PUBLICATIONS

Aiken, R.M. and A.J.M. Smucker. 1996. Root system regulation of whole plant growth. Ann. Rev. Phytopath. 34:324-47.

Aiken, R.M., G.M. McMaster and D.C. Nielsen. 1996. Optimal Wheat *(Triticum aestivum* L.) Cutting Height for Grain Harvest and Conserving Soil and Water. Agronomy Abstracts. American Society of Agronomy.

Anderson, R.L. 1996. Strategies for sod control in CRP conversion to cropland. p. 16-24, in R. Anderson (ed.), Proceedings, 8th Annual Meeting, Colorado Conservation Tillage Association. Sterling, CO. 57 pages.

Anderson, R.L. 1996. Plant and environmental factors affecting systemic herbicide performance. Chap. 7, 7 pages, in Proc. CRP Management Conference, Amarillo, TX. Oct, 1996.

Anderson, R.L. 1996. Enhancing winter wheat tolerance to downy brome. West. Soc. Weed Sci. Res. Rpt. p. 104.

Anderson, R.L. 1996. Investing in the soil seed bank. National Conservation Tillage Digest. March issue:21-23.

Anderson, R.L. and A.D. Halvorson. 1996. Sod control when rotating back to cropland, guided by plant biology. Proceedings, Manitoba-North Dakota Zero-Till Conference. Pages 167-177.

Anderson, R.L., D.J. Lyon, and D.L. Tanaka. 1996. Weed management strategies for conservation-till sunflower. Weed Technol. 10:55-59.

Anderson, R.L. 1996. Controlling perennial grasses key to successful CRP-to-crop conversions. Crop Protection Manager. Jan. issue:10-11. 1996.

Armstrong, J.S. and F.B. Peairs. 1996. Environmental parameters related to winter mortality of the Russian wheat aphid (Homoptera:Aphididae): The basis for predicting winter mortality. J. Econ. Entomol. (89:1281-1287).

Armstrong, J.S., R.E. Lee and F.B. Peairs. 1997. Application of ice nucleating active bacteria, *Pseudomonas syringae,* decreases the supercooling capacity of the Russian wheat aphid (Homoptera: Aphididae). *In* S. Quisenberry and F.Peairs (eds.), Thomas Say Publ. Entomol. (Accepted).

Armstrong, J.S. 1996. Development of a degree-day based prediction model for adult sunflower stem weevil, *Cylindrocopturus adspersus* emergence. pp.49-51. *In Proc.*18th Sunflower Research Workshop, National Sunflower Assoc., Fargo, ND, January 11-12,

Benjamin, J. G., L. R. Ahuja, and R. R. Allmaras. 1996. Modelling corn rooting patterns and their effects on water uptake and nitrate leaching. Plant and Soil 179:223-232.

Bowman, R. A., and M. F. Vigil. Soil organic matter dynamics in intensively cropped systems. ASA Abstr. p. 282. Indianapolis, IN. 1996.

Bowman, R. A. Effect of crop rotation on changes in soil properties. 26th Annual Crop Simulation Workshop. Abstr. p. 6. Fort Collins, CO. 1996.

Bowman, R. A., and R. L. Anderson. Soil organic matter changes in Colorado CRP lands. Proceeding "Preparing for the Future CRP Land Use in the Central and Southern Great Plains." pp. 1-6. Amarillo, TX. 1996.

Bowman, R.A., R.L. Anderson, D.C. Nielsen, M.F. Vigil, and A.D. Halvorson. 1996. Effects of cropping intensity on soil organic matter and aggregate stability. Proceedings, Great Plains Fertility Conference 6:174-183. 1996.

Bowman, R.A. and R.L. Anderson. 1996. Soil organic matter changes in Colorado CRP lands. Chap. 15, 5 pages, in Proc. CRP Management Conference, Amarillo, TX. Oct, 1996.

Bowman, R. A., and M. Petersen. Soil organic matter levels in the Central Great Plains. USDA-NRCS Conserv. Tillage Fact Sheet #1-96. 4 pages. 1996.

Bowman, R. A., R. L. Anderson, D. C. Nielsen, M. F. Vigil, and A. D. Halvorson. Soil organic matter dynamics in Central Plains Cropping Systems. pp. 33-35. National Conservation Tillage Digest. Perryville, MO. Summer, 1996.

Doran, J.W., A. Kessavalou, G.L. Hutchinson, M.F. Vigil, and A.D. Halvorson. Influence of cropping/tillage management on soil fertility and quality of former CRP land in the Central High Plains. 1996. Proc. Great Plains Soil Fert. Conf. vol 6:205-211.

Elliott, N.C., G.L. Hein, M.C. Carter, J.D. Burd, T.J. Holtzer, and J.S.Armstrong. 1997. Russian wheat aphid ecology and modeling on Great Plains agricultural landscapes. *In* S. Quisenberry and F.Peairs (eds.), Thomas Say Publ. Entomol. (Accepted).

Halvorson, A.D., M.F. Vigil, G.A. Peterson, and E.T. Elliot. 1996. Long-term tillage-crop residue management study at Akron, CO. *In* Soil organic matter in temperate agro-ecosystems: Long term experiments in North America. Eldor Paul ed. In press CRC/Lewis publishers. Boca Raton, Florida.

Hammon, R.W., J.S. Armstrong, W.L. Meyer, C.T. Walker and F.B. Peairs. 1996. Non-cultivated host plants of the Russian wheat aphid (Homoptera: Aphididae) in Colorado. Colorado Agricultural Experiment Station Bulletin E-505.

Holtzer, T., R. Anderson, M. McMullen, and F. Peairs. 1996. Integrated pest management for insects, plant pathogens, and weeds in dryland cropping systems of the Great Plains. J. Prod. Agric. 9:200-208.

Johnson Cinthia K., M.F. Vigil, K.G. Doxtader and Bill Beard. 1996. Measuring bacterial and fungal substrate-induced respiration in dry soils. Soil Biol. Biochem. Vol 28, no. 4 pp427-432.

Klein, R., D. Lyon, and R. Anderson. 1996. Returning CRP to crop production in Western Nebraska. p. 105-106, in Proceedings, Univ. Nebraska Crop Protection Clinic. Lincoln, NE.

Kroening, M.K., F.B. Peairs, J.S. Armstrong, R.W. Hammon, W.L. Meyer, and C.B. Walker. 1997. Imidacloprid seed treatments for control of Russian wheat aphid (Homoptera:Aphididae) on winter wheat. *In* S. Quisenberry and F. Peairs (eds.), Thomas Say Publ. Entomol. (Accepted).

Ma, Q. L., L. R. Ahuja, R. D. Wauchope, J. G. Benjamin, and B. Burgoa. 1996. Comparison of instantaneous equilibrium and equilibrium-kinetic sorption models for simulating simultaneous leaching and runoff of pesticides. Soil Sci. 161:646-655.

Nassar, I. N., J. G. Benjamin, and R. Horton. 1996. Thermally induced water movement in uniform clayey soil. Soil Sci. 161:471-479

Nielsen, D., G. Peterson, R. Anderson, V. Ferriera, W. Shawcroft, and K. Remington. 1996. Estimating corn yields from precipitation records. USDA-ARS, NRCS, and Colorado Conservation Tillage Association Fact Sheet #2-96.

Nielsen, D.C., and S.E. Hinkle. 1996. Field evaluation of basal crop coefficients for corn based on growing degree days, growth stage, or time. Trans. ASAE 39:97-103

Nielsen, D.C. 1996. The value of those stalks. The Sunflower 22(2):20,22.

Nielsen, D.C., and S.E. Hinkle. 1996. Managing sunflower residue to reduce wind velocity and ncrease soil water. Agron. Abstracts 88:12.

Nielsen, D.C. 1996. Potential of canola as a dryland crop in northeastern Colorado. pp281-287. In: J. Janick (ed.), Progress in New Crops. Am. Soc. Hort. Sci., Alexandria, VA.

Tanaka, D.L. and R.L. Anderson. 1996. Weed-suppressive canopies of sunflower. p. 94-100, in Proceedings, 18th National Sunflower Association Research Workshop, Fargo, ND.

Tanaka, D.L. and R.L. Anderson. 1996. Weed community response to cultural practices: rotation, tillage, and nitrogen fertility. Proceedings, Manitoba-North Dakota Zero-Till Conference. Pages 107-117.

Vigil M.F., and D.C. Nielsen. 1996. Effect of legumes in green fallow on subsequent winter wheat yields. Proc. Great Plains Soil Fert. Conf. Vol 6:169-173.

Vigil, M.F. and D.C. Nielsen. 1996. Winter wheat Yield depression from legume green fallow. Agronomy Abstracts pg 279.

GREAT PLAINS SYSTEMS RESEARCH UNIT

Lajpat R. Ahuja, Research Leader
Federal Building
301 S. Howes, Room 353
P. O. Box E
Fort Collins, CO 80522
TEL: (970) 490-8300
FAX: (970) 490-8310

INTERNET: ahuja@gpsr.colostate.edu

GREAT PLAINS SYSTEMS RESEARCH UNIT
TABLE OF CONTENTS

CRIS PROJECTS

5402-13660-004-00D	Water Conservation and Water Quality As Impacted By Management and ARS Modular Modeling Framework for Agricultural Systems
5402-61000-002-00D	Global Change Research, Modeling, and Data Base Management with Emphasis On Terrestrial Systems
5402-61660-004-00D	Development of Improved Cropping System Models and Technology for Sustainable Production
5402-61660-005-00D	Development of Improved System Models and Technology for Sustained Rangeland Production
5402-66000-001-00D	Development of A Decision Support System for Farmers and Ranchers in The Great Plains

---

MISSION STATEMENT

Help develop and implement sustainable and adaptive agricultural systems by: (1) synthesizing, quantifying, evaluating, and enhancing knowledge of processes; (2) developing integrated models of agricultural systems; and (3) providing technology packages to agricultural communities and action agencies.

Comprehensive efforts are directed towards: (1) integrated analysis of production, water quality, environmental change, and sustainable on-farm/regional management systems; and (2) creation of decision support systems for on-farm management.

TECHNOLOGY TRANSFER - 1996

Great Plains Systems Research Unit

1. Farmers - Approximately a dozen farmers in the San Luis Valley cooperated in using LEAP to modify their N-fertilizer applications. Forty (40) growers received copies of GWM/WEEDCAM to aide in weed management decisions.

2. NRCS, Extension Service, and other ag-service organizations - Unit scientists provided Unit models to eleven (11) different ag-organizations or government agencies.

3. CRADA - A CRADA was initiated with the Simplot Inc., to embed NLEAP technology in a fertilizer recommendation package.

4. A CRADA was entered into with the Water Resources Publications, of Englewood, CO, for commercialization of the ARS Root Zone Water Quality Model (RZWQM). The purpose is to produce and market a user-friendly and useful new water quality management tool for farm use. Under this Agreement, the RZWQM modeling package will be enhanced and transformed into an easy-to-use product, and made available to agricultural managers, consultants, and other users. The product will consist of a comprehensive technical documentation book and a CD ROM disk containing the computer model and user manual for help.

5. Science and Research Community - Unit scientists continued to work with MSEA projects using RZWQM for evaluation of water quality impacts of cropping systems, they also provided training and consultation to scientist from twelve (12) countries on use of the Unit's software including: RZWQM, NLEAP, SPUR2, and GWM/WEEDCAM. The unit's NLEAP model was incorporated into three (3) existing models.

6. Farmers - Unit scientists participated in six (6) information/discussion sessions with farmer groups including session designed to obtain feedback on GPFARM decision support system.

7. NRCS, Extension Service, and other ag-service organizations - Unit scientists made ten (10) presentations to ag-service organizations on the use of the Unit's models and decision support systems.

8. Science and Research Community - Unit scientists presented four (4) invited papers, and thirty seven (37) volunteered papers.

9. Unit scientists authored or co-authored twenty five (25) refereed journal articles and eight (8) fact sheets or extension publications.

REMOTE SENSING AND SCALING OF SOIL WATER AND ENERGY TRANSFER PROCESS OVER LARGE AREAS

L.R. Ahuja, G.C. Heathman and N. Matakali[1]

PROBLEM: The simultaneous description of moisture and heat energy exchange at the soil surface is an important aspect of the total mass and energy balance in a watershed. Knowledge of the physics of the system, field measurements of the processes of exchange, together with the factors involved with scaling from point to large basins, is required for proper simulation.

APPROACH: This project had two objectives: (1) Investigate the potential of obtaining subsurface soil hydraulic properties from remote-sensed surface soil moisture changes and available soil map information using the Root Zone Water Quality Model (RZWQM); (2) Evaluate the convergence scaling theory for integrating water and energy fluxes over large areas. For Objective 1, the remote-sensed and gravimetrically measured surface moisture data from several parts of the Little Wachita watershed in 1992 will be utilized. First estimates of subsurface soil hydraulic parameters will be obtained from available soil survey data on texture and bulk density using the SOILPROP subroutine of RZWQM. These estimates will then be refined by calibrating the RZWQM-simulated values of surface moisture changes against the measured values. The final calibrated estimates will be validated against field measurements for selected cases. For Objective 2, the RZWQM model will be linked to GIS technology and the databases (soils, topography, climate, channels) for the Little Wachita Watershed. Starting with uniform initial conditions and assuming uniform weather conditions, the model will be run for each pixel to generate data on water and heat fluxes. The scaling of these fluxes with respect to scaling of soil hydraulic parameters will then be explored.

RESULTS: Steady-state infiltration rates, drainage in two days, and water retention for several different horizons have been measured for 10 sites of the Little Wachita Watershed. The data are being analyzed for Objective 1.

FUTURE PLANS: The above calibration method will be validated against theoretical surface water content data generated by numerical solutions for three different soil types. In addition, the method will be tested in the field at the 10 locations. Later, the work outlined above for Objective 2 will be undertaken.

---

[1]NASA-GSFC, Hydrologic Science Branch, Greenbelt, MD

FIELD DECOMPOSITION RATES AND SOIL COVER OF SURFACE CROP RESIDUES

R.M. Aiken, M. Vigil, G. Uhler and M.J. Shaffer[1]

PROBLEM: Surface crop residues reduce soil erosion and can improve soil water storage, conditioning the biological environment of crop seedlings and associated pests. Decomposition of surface residues alter these benefits and biological risks, and may compromise conservation compliance of dryland cropping systems. Knowledge of environmental factors altering decomposition rates can guide surface residue management.

APPROACH: Seasonal decomposition rates of surface crop residues (wheat, millet and corn) were measured under field conditions using litter bags, screen shelters and grab samples, collected at 1000 degree day intervals. Changes in biochemical composition of residues were sampled at initial, mid and final stages of field exposure. Accumulation of surface crop residues in various wheat, corn and millet crop sequences of the Alternative Crop Rotation study was determined pre-plant and post-harvest over four crop seasons. We quantify daily temperature effects on decomposition rates using a first order rate model, scaled to thermal time (cumulative degree days).

RESULTS: Field sampling was completed and sample processing is near completion for controlled residue placement. Dry surface conditions and high carbon:nitrogen ratios resulted in similar decomposition rates among dryland grain crops. First order rate constants, scaled to thermal time, appear consistent for lab and field data available for wheat, corn and millet residues. The half-life of standing plus surface residues appears to be 5800 °C day, about 1.5 years of calendar time, while a shorter half-life for surface residues under wet soil conditions indicates more rapid decomposition.

FUTURE PLANS: Processed residue samples will be submitted for biochemical analysis. We'll evaluate relationships among diagnostic residue attributes and environmental factors altering decomposition rates and soil cover. Manuscript reporting results will be submitted for publication, subject to peer review.

---

[1]Great Plains Systems Research

SEASONAL RESIDUE IMPACTS ON RADIATIVE AND CONVECTIVE EXCHANGE PROCESSES

R.M. Aiken, D. Nielsen and L.R. Ahuja[1]

PROBLEM: The distribution of standing and flat surface crop residues condition the habitat of crop seedlings and associated pests. Cooler and wetter soils, associated with no-till crop management, alter decomposition rates of surface residues as well as soil quality factors impacting water management. Knowledge of residue effects on surface microclimate and subsequent processes can guide soil and water management.

APPROACH: We installed radiation, temperature, wind and soil water sensors in 10 m x 30 m plots of standing wheat, millet, corn and sunflower residues following harvest. Hourly data acquisition was screened for sensor reliability prior to archiving for subsequent analysis. Sheltering and insulating effects of crop residues are quantified as solar reflectance and wind velocity at 0.2 m relative to reference wind speeds at 2.0 m. Cover of flat residues and persistence of standing stems were sampled periodically. An energy balance simulation module of the Root Zone Water Quality Model quantified residue effects on evaporative demand.

RESULTS: Data acquisition is completed for fallow periods through pre-plant tillage for wheat, millet, corn and sunflower residue. Preliminary data analysis indicates soil-crop residue systems differ in absorbed solar radiation, in relative windspeed at 0.2 m, and in near surface temperature dynamics. Simulation results indicate the shading and insulating effects of crop residues can reduce potential evaporation by 30 to 70%, relative to bare soil, under wet soil conditions.

FUTURE PLANS: Data analysis will identify relationships among residue attributes (reflectance, silhouette factor, etc.), and exchange processes (radiation, convection). Data will provide independent evaluation of energy balance modules of the Root Zone Water Quality Model for winter and non-freezing conditions. Manuscripts reporting results will be submitted for publication, subject to peer review.

---

[1]Great Plains Systems Research

STRUCTURAL COMPONENTS OF STEM STRENGTH FOR WHEAT CULTIVARS

R.M. Aiken, M. Vigil, G.H. Dunn[1] and J. Shanahan[2]

PROBLEM: Standing crop residues insulate the soil from erosive and evaporative winds in semi-arid climates. These benefits decline as strong winds blow over decaying residues. Variation in stem strength alter susceptibility of crop cultivars to lodging as well. Rapid quantitative screening tools indicating stem persistence can enhance selection of superior cultivars.

APPROACH: Quantitative measures of stem strength provide tools for evaluating cultivar susceptibility to lodging and standing stem persistence. We used the cantilever principle to measure structural components of stem strength (shape factors and intrinsic strength) for the upper three internodes of nine wheat cultivars. We also determine biochemical properties of internode segments.

RESULTS: Stem measurements and data collection are completed. Preliminary analysis indicate the intrinsic strength of wheat stems is similar to that of wood. Variation in stem strength among wheat cultivars appears to result from diameter and thickness of stem walls. Rapid and inexpensive stem strength measurements could be incorporated in varietal selection programs.

FUTURE PLANS: We will test for significant differences in stem strength among the selected cultivars. Also, we'll evaluate the relationships of stem strength components with biochemical fiber analysis and field lodging observations of the selected cultivars. Manuscript reporting results will be submitted for publication, subject to peer review.

---

[1]Great Plains Systems Research,

[2]Colorado State University

SIMULATING YEAR-ROUND ENERGY AND WATER FLUX UNDER CROP RESIDUES

R.M. Aiken[1], G.N. Flerchinger[2], L.R. Ahuja, H.J. Farahani and K.W. Rojas

PROBLEM: Residue architecture (standing height, percentage soil cover, reflectance, etc.) Modifies soil warming and water conservation by shading and 'insulating' surface soil layers. Decay of residue, dependent upon temperature and water conditions, results in seasonal changes in residue architecture, with impacts on soil temperature and water status. Accurate simulation of energy and water exchange processes provide analytic tools guiding residue management.

APPROACH: Crop residue impacts on energy and water exchange are quantified by PENFLUX, a soil-residue energy balance module providing boundary conditions for soil heat and potential evaporation modules of the Root Zone Water Quality Model (RZWQM). Year-round simulation of residue impacts by RZWQM is provided by incorporating energy exchange modules of SHAW, a process-level simulation model including freeze-thaw thermal dynamics of soil. Predictive accuracy of energy balance simulation is determined by comparing simulation results with micrometeorological observations acquired under dryland wheat, corn, sunflower and millet residues.

RESULTS: We completed merger of SHAW soil heat processes into a beta test version of RZWQM, verifying simulation consistency with previous RZWQM results for a MSEA water quality demonstration site. Field data acquisition (reported in Central Great Plains Research Station) indicated surface residues enhance soil water conservation via effects on near-surface microclimate. A manuscript describing the PENFLUX module is accepted for publication in Agronomy Journal.

FUTURE PLANS: The PENFLUX module requires a companion residue water balance, under development, for accurate simulation of thermal conditions following precipitation/dew accumulation events. Further evaluation of RZ-SHAW and PENFLUX modules will utilize extensive micro-meteorological data acquired at Pullman, WA; Fort Collins, CO; and Akron, CO representing a range of residue architectures in semi-arid climates. Manuscripts reporting the predictive accuracy of these modules under winter and non-freezing conditions are in preparation.

---

[1]Central Great Plains Research Station

[2]Northwest Watershed Research Center

DEVELOPMENT OF A FARM SPATIAL DATA MANAGEMENT SYSTEM MODULE FOR GPFARM

James Ascough II, David G. Wagner and Brenda G. Faber

PROBLEM: A farm spatial data management system (FSDMS) is necessary for transforming data from a georectified map or nongeorectified image format to a data format acceptable to GPFARM. The selection of areas having homogeneity for simulation by GPFARM requires geographic information system (GIS) functionality for evaluating a variety of GIS data layers representing different spatial attributes, not necessarily spatially coincidental. An additional capability of the FSDMS is the capability of providing map and table output for storage and management of attributal data relating to the maps or images.

APPROACH: The project uses Environmental Systems Research Institute, Inc. ARCVIEW 3.0 as the base software. Modifications to the software are done with AVENUE, a scripting language specific to ARCVIEW. ARCVIEW is a GIS designed specifically for viewing, modifying and storing image and map data. Modifications to the software are made to tailor the GIS and related sketching, mapping and attribute storage information to the GPFARM data input and output requirements. The FSDMS anticipates three different user groups characterized by 1) different levels of information storage and mapping needs and 2) by differing levels of experience with GIS technologies. Level One capability, presumes that users will import and store non-georectified images and related attribute data. This spatial data may be converted to map information (georectified to a geographic coordinate system) in the future. Level Two provides the user with capabilities to import maps and map attribute data. This increasingly complex usage level also provides GPFARM interface capability primarily focussed toward the cooperator or agricultural consultant who will use the geospatial capabilities of the FSDMS in conjunction with GPFARM simulation procedures. Level Three provides the researcher with full GIS tools for conducting research-level geospatial analysis with GPFARM. Two cooperator's farms have been selected to provide baseline data layers for testing and developing the FSDMS; 1) an irrigated farm and 2) a four section dryland wheat farm. The FSDMS is developed to run under Windows 95 and Windows NT.

RESULTS: The development of the FSDMS is coincidental with the development of GPFARM. The FSDMS Level One and parts of Level Two will be able to be linked to GPFARM during the summer of 1997. Customized on-line help screens are being developed to assist the users with the customized parts of the FSDMS.

FUTURE PLANS: Level Two will be completed in late 1997 and Level Three will be completed in 1998. Level Three is planned to include neural network/artificial intelligence-based prescriptive farming components to complement and use the simulation outputs of GPFARM. In addition, the conversion of the FSDMS to an OCX-based software format is considered to be a major step toward increasing the efficiency of the FSDMS when used in conjunction with the Internet.

MINIMIZING CHEMICAL LEACHING BY ALTERNATE FURROW IRRIGATION AND FERTILIZER BANDS

J.G. Benjamin, L.R. Ahuja, H. Ruan, G. Butters[1], L. Porter and H. Duke

PROBLEM: High nitrate levels in groundwater in the Great Plains has been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on crop land and yet minimize adverse environmental effects.

APPROACH: An irrigation-nitrogen placement experiment for irrigated corn production was established in 1994 at ARDEC (Agricultural Research, Demonstration, and Education Center) at Ft. Collins, Colorado. Two irrigation water placements, alternate furrow irrigation (AF) and every furrow irrigation (EF), and two nitrogen placements, in-furrow (IF) and in-row (IR), were tested to determine the plant use of the nitrogen fertilizer and nitrate leaching in the soil. Labeled 15N fertilizer was used to differentiate fertilizer nitrogen from naturally occurring nitrogen in the plant and the soil. Corn physiological development, biomass, total nitrogen uptake, fertilizer nitrogen uptake, corn yield and yield components were measured during the growing season to determine the effects of irrigation water placement on crop growth and the availability of nitrogen to the plant with the various placement options.

RESULTS: An irrigation-nitrogen placement experiment established in 1994 was continued in 1996 at Fort Collins, CO. Alternated furrow(AF) and every furrow (EF) irrigation with in-furrow placement (IF) and in-row placement (IR) of labeled 15N fertilizer nitrogen were tested to determine plant use of nitrogen fertilizer and nitrate leaching in the soil. Corn development, biomass, yield, fertilizer nitrogen uptake, water contents before and after irrigation, and fertilizer nitrogen distribution at the end of the growing season were measured to determine treatment effects on the crop and on fertilizer leaching. There were no differences in plant response to AF or EF irrigation water placement for the same amount of water applied. Greater fertilizer N uptake occurred with IR than with IF placement of N fertilizer. Early in the growing season, fertilizer N uptake from IR was from 2 to 10 times the fertilizer N uptake from IF. By the end of the growing season, the average total N uptake from IR was 12% greater than for IF. Placing the fertilizer in the non-irrigated furrow of the AR irrigation treatment decrease N availability by 20%. In 1994, fertilizer N leached to about 1 m under the irrigated furrow but less than 0.5 m for fertilizer placed in the nonirrigated furrow or in the row. In 1995, which had more rainfall and less irrigation water applied, the leaching for all treatments was less than 0.5 m. A 2-d water-N-corn model is being tested against these data.

FUTURE PLANS: Data analysis from the 1996 study will be completed. Modeling studies will be conducted to expand the findings from the field study to other irrigation rates and placements.

---

[1]Department of Soil and Crop Sciences, Colorado State University.

INSTALLATION OF THE ROOT ZONE MODEL INTO THE MODULAR MODELING SYSTEM (MMS)

Chad Bierbaum

PROBLEM: MMS is a software developed by the USGS for the purpose of providing a common framework for the development and testing of process based modules and to facilitate integration of these process modules into operational physical models. By providing a consistent framework for model development and application, it is hoped that the installation of the Root Zone Model in MMS will enhance the integration of related ARS process modules into the model. In addition, the graphical interfaces supported in MMS assist users in parametetrization of model components and the visualization of model output. This installation will demonstrate the efficiency of implementing research models within a common framework and provide a tool to focus multidisciplinary research efforts.

APPROACH: Define distinct process modules within in the Root Zone Model which serve as the basic building blocks for the overall combined model structure in MMS. When these modules do not satisfy the required MMS coding structure, rewrite the module source code while maintaining the same functionality and capabilities as the unmodified version of RZWQM. Within each of the identified process modules, define a consistent naming convention for that module's input parametetrization variables and output display variables. This convention should produce a concise name which is consistent with current scientific nomenclature and provides the user with a clear understanding of the variables context within the associated process module.

RESULTS: Version 3.0 of the Root Zone Water Quality Model has been implemented into the MMS software. This implementation is an initial test version which will require some additional restructuring of the modules and further instructional documentation to achieve the expressed goals as outlined above. However, this initial work has demonstrated that efficient incorporation of process modules can be enhanced within the MMS system; as two process modules from the USGS-Precipitation Runoff Modeling System have been integrated as modules into the Root Zone Model.

FUTURE PLANS: Further segregation of the current modules will help promote interaction with RZWQM at a more basic algorithmic level. With this additional segregation, it is felt that the MMS platform will be a valuable tool for efficient installation of new process modules into RZWQM, and that this platform will also assist the Agricultural Research Service in examining the potential of MMS as a common software for all ARS models. In addition, a more clearly defined variable naming structure and additional on-line module documentation, will provide users with a complete understanding of variable/process association and model capabilities. Finally, a variety of graphical and post-processing tools will further assist users in the visualization and assessment of modeling results.

ENHANCEMENT AND REFINEMENT OF NLEAP TO MEET USER NEEDS

M.K. Brodahl, M.J. Shaffer and P.N.S. Bartling

PROBLEM: Agricultural and software technologies are changing rapidly. Precision agriculture is a new, imerging technology heavily dependent on software technolgy and our ability to model and predict agricultural systems for its successful implementation. These applications are making new demands of our models. The potential of the Internet for increasing the users access to information and software technology is tremendous. Internet and client-server systems for software use will change software distribution, support, and maintenance strategies. Continuing through these changes and advances, there is still the need to enhance the use of models such as NLEAP for addressing agricultural and envrionmental issues within State and Federal agencies, within government agencies of other countries, with private consultants, and in education of the agricultural community.

APPROACH: Re-programming continues to be done in object-oriented design using C++ and in Fortran to facilitate the use of NLEAP technology by end users in other related software applications and to move into the client-server delivery of software. As we upgrade the simulation portions, we will include enhancement of the program for precision farming applications including: incorporation of more flexible and user-defined program configuration, execution, and I/O; improvement of crop nitrogen and water uptake in response to changes in crop state due to environmental or pest stresses; management event scheduling; simulation over environmental units within a field; and I/O and file handling for batch and GIS applications. Once this is accomplished, we will build a new user interface for cross platform delivery of the program. Any re-design of the program will take into account how the user interacts with the software.

RESULTS: Enhanced NLEAP model treatment of changing root depths over crop rotations and tracking of crop nutrient and water uptake in multi-year simulations have been made and distributed to ARS researchers for testing. The NLEAP crop and nutrient programming has been restructured and re-programmed in Fortran for the J.R. Simplot programming needs expressed in our CRADA. Development of the NLEAP nutrient technology continues to be re-programmed to work within the framework of GPFARM. Work continues on the upgrading, expansion and redesign of the NLEAP software using object-oriented programing in C++ and Fortran. Programing efforts continue to be made in the simulation portion of the model. Improvement of event scheduling within the program has been initiated in the development of a rule-based event implementation. Though this was explicitly developed for GPFARM, it was designed so that it could also be used with other programs including NLEAP.

FUTURE PLANS: Continue development of NLEAP simulation components in object-oriented C++. Development of the NLEAP program and its interface for cross-platform performance, movement into client-server delivery of the model, and for interaction with GIS software. Provide programming and technical support for our CRADA with J.R. Simplot Company.

EFFECT OF TILLAGE VS. NO-TILLAGE ON INFILTRATION

G.H. Dunn, G.S. McMaster and L.R. Ahuja

PROBLEM: Tillage operations, specifically moldboard plowing and discing, are known to affect soil physical and chemical properties. The change in physical properties appears to be ephemeral. Several physical properties, including infiltration and bulk density go through a continuum of values beginning at plowing and progressing through the growing season arriving back at values very similar to the starting point. The soil reconsolidation process has quantifiable beginning and ending points. The in-between processes need to be parameterized and studied because an effective understanding of the process would allow for testing changes in management that would reduce runoff and erosion.

APPROACH: Ponded- and tension- infiltration were measured on conventionally tilled and no-till plots to evaluate the effect of tillage on infiltration and macroporosity. The ponded infiltration measurements assess near-steady state conditions over a relatively large area and are influenced by soil stratification as well as pore size distribution. Tension infiltration measurements focus on infiltration in defined effective pore-size ranges and allow for quantification of macropore flow in tilled and untilled soil. Both measurements are important indicators of the effects of reconsolidation on tilled soils. In addition, published data from several sources on soil water retention as affected by tillage and reconsolidation are available. We will attempt to quantify the differences in soil water retention/suction relationship of a soil in its tilled condition vs. untilled or the final reconsolidated condition.

RESULTS: Analysis of the infiltration data is progressing and early results indicate a weak relationship between no-tillage and higher ponded infiltration. Tension infiltration also shows some weak trends especially for water flux in specific pores size ranges. Analysis of the soil water retention data is being tested to see what form of the function gives the best fit.

FUTURE PLANS: Following complete data entry we will test for statistical significance differences in infiltration and tension infiltration as affected by tillage. Mathematical analysis of the water retention data will provide information on the nature of soil reconsolidation. A field experiment will be conducted to test the empirical results of the mathematical analysis. Each research effort will result in the production of a manuscript for publication.

LONG-TERM EXPERIMENTAL ANALYSIS AND RZWQM TESTING OF DRYLAND CROPPING SYSTEMS IN COLORADO

H.J. Farahani, L.R. Ahuja, G.A. Peterson, G.S. McMaster,
J.D. Hanson, Chad Bierbaum and L.R. Sherrod

PROBLEM: Mathematical models of agricultural systems are a synthesis of the current state of knowledge and can be used as a tool to aid in extrapolating management effects outside the experimental location. Models, however, must be field tested to assess their consistency.

APPROACH: In 1996, we completed the cooperative work of testing RZWQM with scientists in the MSEA Project. The interest was to compare seasonal measured with model predicted values for crop yield and the various components of the soil water and nitrogen budgets, including ET, deep seepage, nitrogen uptake, and nitrogen leaching below the root zone. For the purpose of MSEA, we tested the model against seasonal measurements from center-pivot and dryland corn production systems in Colorado. Model testing was then extended to include long-term (85-95) experimental data from dryland cropping systems in eastern Colorado. In 1996, we explored the fundamental concept in dryland cropping intensification as it relates to efficient use of precipitation. The RZWQM model tested by MSEA is capable of simulating effects of management on corn and soybean crops. The ARS SHOOTGRO wheat growth model was linked to RZWQM to simulate wheat-fallow and wheat-corn-fallow cropping systems in eastern Colorado.

RESULTS: Findings from the RZWQM modeling work with MSEA produced a seven-paper series, one from each state, that was submitted to Agronomy Journal for publication. These papers, currently in review, are expected to be published in 1997. For the Colorado sites, seasonal comparison of model output against measured data deviated from zero to 30% for crop water use, soil water, seepage of water and nitrate below root zone, nitrogen uptake, and grain yield/biomass production. Model strengths and deficiencies were identified. At present, calibration and parameterization of the model seems unnecessarily complicated. It is currently being simplified by providing the user with a range of default values and detailed calibration and parameterization procedures. The effects of water stress on plant growth requires additional work. Inclusion of the effects of residue architecture on soil and crop energy balance will improve simulation of no-till and stubble-mulch tillage. In regard to exploring dryland cropping sysytems, analysis of raw data was completed and results presented in the 1996 October meeting of the GPSR Customer Focus Group. Results clearly show that efficient use of precipitation is enhanced in more intense wheat-corn-fallow than in wheat-fallow systems. Results were prepared for journal publicaiton.

FUTURE PLANS: Long-term testing of model behavior against a decade long field data was initiated in December, 1996. We expect to complete this latter task by spring of 1997.

THE RAINFALL-RUNOFF PROCESS ON SEMI-ARID RANGELANDS: MEASUREMENTS OF INFILTRATION AND OVERLAND FLOW

F.R. Fiedler[1], G. Frasier[2], L.R. Ahuja and J. A. Ramirez[1]

PROBLEM: Optimization of plant and animal production from semi-arid rangelands is dependent on management of a limited water supply. Grazing intensity affects the rainfall-runoff process, with higher grazing intensities leading to decreased infiltration leaving less water available for plant growth. The effect of grazing on infiltration characteristics and overland flow is the focus of this study.

APPROACH: Four experimental plots were established on the Central Plains Experimental Range in areas representative of light- and heavy-grazing intensities. Rainfall-runoff simulations were performed, including measurement of outflow hydrographs and spatially variable overland flow depths and velocities. Plot microtopography was measured with a laser profilometer. Tension infiltrometers were used to estimate hydraulic conductivities of bare and vegetated soil at each grazing intensity, and statistical analyses were performed to determine potential differences. These data were used to evaluate grazing effects and develop a numerical model of the rainfall-runoff process.

RESULTS: Visual observations and data analysis indicate: heavy-grazed plots produce more runoff than light-grazed plots; microtopography forces overland flow to occur in small channels; bare soil generally corresponds to microtopographic lows, and vegetated soil to highs; vegetated soil is much more hydraulically conductive than bare soil; and heavy-grazed vegetated-soil hydraulic conductivity is significantly less than light-grazed vegetated-soil conductivity. The data suggest that grazing reduces infiltration volumes by reducing the hydraulic conductivity of vegetated locations, which in turn reduces further growth of grasses. The mechanism through which hydraulic conductivity decreases are manifested is a reduction of plant root growth, thus decreasing the number and connectivity of macropores. Thus, optimal grazing intensity should exist at the point where grassed-patch infiltrability is not reduced and the forage is not affected by lack of available water. These data were also used to conceptualize a mathematical model of overland flow which allows for the interactive infiltration that occurs because of the relationship between hydraulic conductivity and microelevation and small-scale spatial variablity of infiltration characteristics.

FUTURE PLANS: The collected data and observations will be used to further develop the conceptual and mathematical model of overland flow, and to explore methods of upscaling the effects of small-scale variability and process interaction.

---

[1]Department of Civil Engineering, Colorado State University.

[2]USDA-ARS, Rangeland Resources Research Unit, Fort Collins, CO.

THE RAINFALL-RUNOFF PROCESS ON SEMI-ARID RANGELANDS: 2. MODELING SPATIALLY VARIABLE OVERLAND FLOW

F.R. Fiedler[1], J.A. Ramirez[1] and L.R. Ahuja

PROBLEM: Optimization of plant and animal production from semi-arid rangelands is dependent on management of a limited water supply. Measurements of spatially variable infiltration and overland flow indicate that the small-scale spatial variability of parameters and process interactions are important to areal-average infiltration and runoff. A mathematical model of the physical process is useful for prediction of grazing effects, and is the focus of this study.

APPROACH: Observations and measurements indicate that the conceptual model must include consideration of microtopography, spatially variable infiltration characteristics, and their relationship to one another. As such, the full hydrodynamic overland flow equations were used as the basis for the surface water component, and the Green-Ampt equation was used in a manner that allowed fully interactive infiltration. The MacCormack explicit finite difference scheme, second-order accurate in time and space, was used to integrate the hydrodynamic equations. Modifications to the basic scheme were necessary to simulate the physical system: the friction slope term is treated point-implicitly, the convective acceleration term is upwinded, and a high-order smoothing function was added.

RESULTS: Results from the developed model were compared to several test cases. When compared to steady-state kinematic wave solutions produced for planes where the kinematic wave approximation is valid, percent differences in depth and discharge are only a few tenths of a percent. Model results compared excellently with the analytical dam-break solution. Model results also favorably compared to recently published results obtained with a characteristic-based solution of the kinematic wave approximation for uniform and spatially variable hydraulic conductivities on a plane. Based on these comparisons, the developed model appears to be reasonably accurate. Additional test simulations show that the developed model can handle the large gradients, shock waves, and discontinuous flow regimes resulting from microtopography and infiltration spatial variability. Results of simulations performed to explore the effects of grazing indicate that: interactive infiltration is an important process, vegetated-soil hydraulic conductivity decreases alone can decrease infiltration volumes, and the areal extent of vegetation greatly affects infiltrated volumes. The rainfall-runoff process is seen to be sensitive to the effects of grazing-indeced vegetation changes.

FUTURE PLANS: More simulations will be performed to better quantify the effects of grazing. Model results will be used to develop methods to upscale the effects of small-scale variability and process interaction (interactive infiltration).

---

[1]Department of Civil Engineering, Colorado State University.

DEVELOPMENT OF A DECISION SUPPORT SYSTEMS FOR FARMERS AND RANCHERS IN THE GREAT PLAINS

GPFARM Development Team: J.A. Ascough II, M.J. Shaffer, G.S. McMaster, L.J. Wiles, B. Vandenberg, P.N.S. Bartling, D. Edmunds, L. Deer-Ascough, H. Yin and L.R. Ahuja

PROBLEM: Maintenance of sustainable agriculture in the Great Plains is a complex problem requiring consideration of a range of interrelated factors, processes, and institutions. Past management practices and Federal programs have created special environmental, managerial, economic, and political needs that must be addressed. The ability to analyze and modify farm and ranch management practices to take advantage of the changing global economy; new cropping, pest management, and tillage systems; and future legislation while protecting environmental resources, will determine whether an agricultural enterprise system survives or perishes.

APPROACH: The Great Plains Framework for Agricultural Resource Management (GPFARM) decision support system (DSS) is being developed to analyze and develop strategic 1-10+ year management plans. GPFARM will provide an operational framework for farm/ranch decision support from which alternative agricultural strategies can be developed and tested. Strong emphasis will be placed on simultaneous analysis of profitability and environmental protection through the development of an economic budgeting package and an object-oriented framework integrating the interface, science modules, and databases. Future versions of GPFARM will include components for GIS, multiple criteria decision analysis, and risk analysis.

RESULTS: GPFARM development has progressed to the beta delivery stage. The graphical user interface (GUI) component has been completed. Linkages between the GUI, the science modules, and the databases have been completed and are being tested. All databases required for GPFARM beta version delivery have been populated: including soils, chemicals (pesticides, insecticides, and fungicides), weed information, and farm equipment. A rule-based system was developed that allows on-farm management events to be simulated based on rules supplied by the producer or consultant. Other enhancements to the general GPFARM framework include the development of: (1) a combination technology transfer/information management system, for the organization and display of electronic documents (e.g., extension fact sheets) related to Great Plains agriculture; and (2) a comprehensive farm record keeping component. Work is also progressing on the spatial component of GPFARM, which will give targeted users the ability to import and manipulate geo-referenced maps of their field boundaries, oils, land use history, etc., and to spatially display GPFARM output. The weed module was improved with enhanced databases and making weed population a function of density.

FUTURE PLANS: The screen design will be modified and enhanced based upon input from intended customers. Development of the databases and science modules will continue. The beta version will be tested on cooperators farms and improved as needed.

EVALUATION OF PREFERENTIAL FLOW COMPONENT OF RZWQM (V. 3.25) IN SIMULATING ATRAZINE TRANSPORT TO SUBSURFACE DRAIN LINES

Ajay Kumar[1] and R.S. Kanwar[1]

PROBLEM: Computer simulation models such as RZWQM provide a cost-effective and time saving alternative to lengthy and expensive filed studies for evaluating various agricultural management options. However, the model performance has to be critically evaluated against observed data collected in the controlled experiments before the model can be accepted as a tool for evaluating management scenarios. This project focuses on the critical evaluation of the model performance.

APPROACH: The ARS Root Zone Water Quality Model (RZWQM V. 3.25) was used to simulate the effect of filed measured macroporosity on atrazine transport to subsurface drain lines. Field data on atrazine concentrations in subsurface drain flows, for no-till (NT) and modelboard plow (MP) systems, were used to evaluate the performance of the RZWQM for the growing seasons of 1990, 1991 and 1992. Simulated subsurface drain flows and atrazine losses with and without macropore flow were compared with measured values.

RESULTS: Simulated subsurface flows were close to the observed values. Although preferential flow slightly improved the predictions of peak subsurface drain flows for individual rain storms, it did not affect significantly the total annual flows. Simulated atrazine concentrations in subsurface drain flows with mean macroporosity were in close agreement with the observed concentration. Predicted total annual atrazine losses were also close to the observed values. The simulated atrazine losses for NT plots were within +5.1% of observed values. The RZWQM predicted only trace amounts of atrazine in subsurface drain flows if macropores were not considered. The model also showed the sensitivity to lateral flow from macropore, K_{sat} of surface layer, and macroporosity in decreasing order in simulating atrazine losses to subsurface drain flows. Overall, the RZWQM showed a good potential for simulating atrazine losses with subsurface drain water as affected by various tillage practices.

FUTURE PLANS: Future plans include: a) calibration and evaluation of the manure component; and b) simulate long-term impacts of chemical (multiple N- application, banding, manure application, etc.), management and crop rotation on water quality.

---

[1]Agricultural and Biosystems Engineering Dept., Iowa State University, Ames, IA.

TESTING RZWQM FOR MANURE MANAGEMENT UNDER FIELD CONDITIONS

L. Ma, M.J. Shaffer and L.R. Ahuja

PROBLEM: Animal waste disposal has received great attention in agriculture for the last decade. Many studies have shown that extensive use of animal wastes on agricultural land may cause potential contamination of groundwater and surface water bodies. Therefore, it is necessary to develop improved management practices for manure. The RZWQM was developed to simulate management effects on leaching of nitrates under an range of management conditions, but requires testing for manures.

APPROACH: Two sets of field experiments with beef or chicken manures were selected to test the RZWQM. One is from Colorado, where beef manure was applied continuously to a corn field for more than 10 years, and the other is from Arkansas, where chicken manure was applied to a tall fescue field which had not received any fertilizers for many years prior to experiment. In both fields, crop nitrogen uptake, nitrate in the soil profile, and soil water content were measured periodically. The results were used to calibrate the RZWQM for soil water content, matrix potential, temperature, total nitrate in the soil profile, and crop yields. The calibrated model was then used to simulate long term effects of manure management under the specific field conditions.

RESULTS: The calibration of RZWQM for the Colorado data set was satisfactory with regard to crop yields, total nitrate, and soil water content in the soil profile. Based on simulation results of the calibrated model, the current manure management practice (44800 kg/ha/year) caused extensive nitrate losses to the environment through leaching, denitrification, and volatilization. Reducing manure and water application rates by 50% would not reduce corn yield significantly, but would considerably decrease nitrate loss to the environment. The testing process is still underway for the Arkansas data set. Initially, results have shown good model comparisons with measured soil water content, matrix potential, and soil temperature at several depths for the Arkansas data.

FUTURE PLANS: We will further parameterize the RZWQM for the Arkansas experimental site and make recommendations for manure application to grassland.

DEVELOPING AND EVALUATING SHOOTGRO, A CEREAL GROWTH AND DEVELOPMENT MODEL

G.S. McMaster and W. W. Wilhelm[1]

PROBLEM: To better understand crop responses to management practices and environmental factors, both physiological and developmental processes must be considered. Almost all current cereal models are fundamentally similar in that they are physiologically driven and simulate on the canopy level or higher. The general approach is that they estimate canopy light interception (based on LAI, incoming radiation, and canopy light extinction coefficients) to predict photosynthesis, and then allocate the carbon and nitrogen to general plant components such as leaves, roots, and grain. Simplistic phenological submodels provide the framework for altering physiological rates and events. Little attention is given to critical developmental processes, and most of the vast cereal developmental research conducted since 1980 is not incorporated into these models.

APPROACH: A group of ARS and university scientists are collaborating to develop a simulation model, called SHOOTGRO, that incorporates the latest research and concepts on cereal development and physiology. Many important developmental concepts are shared by cereals and other grass crops, so that one approach can be used to simulate them. A basic premise of SHOOTGRO is that if it is to accurately simulate responses to management practices, the effects of the management practices on fundamental factors such as temperature, nutrients, water, and light should be simulated first. In turn, all simulated plant processes must be modeled sufficiently to be able to respond to changes in the fundamental factors resulting from management practices.

RESULTS: The developmental sequence of the corn shoot apex was determined, which is the first step required to convert SHOOTGRO from simulating wheat and barley to corn. The effect of using soil temperature rather than air temperature to predict wheat phenology was tested. It was found that unless subtle phenological responses to management practices such as tillage are required, there is no justification for the extra effort and expense of using soil temperature. A comparison of the SHOOTGRO, CERES-wheat, and PUTU wheat simulation models for South African conditions and spring wheats was completed. SHOOTGRO predicted development and phenology better than the other models, especially under varying water and N conditions. Yield prediction was similar among all three models. CERES-wheat tended to predict biomass and LAI a little more accurately. SHOOTGRO was coupled with non-crop components of the RZWQM model using the Modular Modeling System.

FUTURE PLANS: SHOOTGRO is to be expanded from simulating wheat and barley to corn. Further testing of SHOOTGRO will be continued, particularly comparing SHOOTGRO, MODWht32, and ModWht++.

---

[1]USDA-ARS, 119 Keim Hall, University of Nebraska, Lincoln, NE 68583

DRYLAND WINTER WHEAT PRODUCTION SYSTEM RESPONSES TO SOIL MANAGEMENT PRACTICES

G.S. McMaster, R.M. Aiken, G.H. Dunn and L.R. Ahuja

PROBLEM: Different soil management practices are currently available and being promoted. In dryland wheat production systems, no- or low-tillage practices that preserve residue cover are being promoted. Studies on how wheat develops and grows have focused on responses to fundamental factors such as temperature, water, nutrients, light, and CO_2 under more "traditional" agronomic practices. Because wheat can reach final grain yield in many ways, understanding how and why wheat responds to alternative soil management practices is needed.

APPROACH: We believe that first we need to understand how soil management practices alter fundamental factors such as soil temperature, water, and nutrients. Changes in these fundamental factors can then be measured for their effect on wheat physiology and development, and therefore help us understand better why the observed yield differences occur. Starting in 1991, pre-plant tillage practices (conventional tillage, CT; no-till, NT) and residue cover levels (no residue, 0R; normal residue, 1R; twice-normal residue, 2R) have been tested. Soil and air temperatures, soil water, soil nutrient levels, and heat and gas fluxes over time are being followed, and subsequent responses in wheat development and growth observed.

RESULTS:

	Yield (bu/ac)							
	No-tillage				Conventional Tillage			
Year	0R	1R	2R	ALL	0R	1R	2R	ALL
1992-93	89	92	90	90	93	83	89	89
1993-94	54	62	64	60	58	61	60	60
1994-95	36	36	35	36	21	25	29	25
1995-96	50	48	51	50	44	46	48	46

No-tillage yields are as high or higher than in pre-plant conventional tillage. Regardless of tillage system, the timing and pattern of seedling emergence is a major factor controlling final grain yield. No-till systems have lower risk of insufficient soil water for germination and emergence because water is not lost due to tillage, and therefore dependence on fall precipitation to replace seedbed soil water lost due to tillage is less.

FUTURE PLANS: This long-term experiment will be continued.

OPTIMIZING WHEAT HARVEST CUTTING HEIGHT, SOIL EROSION, AND WATER CONSERVATION

G.S. McMaster, R.M. Aiken[1] and D.C. Nielsen[1]

PROBLEM: When harvesting wheat, custom combine operators typically set the cutter bar as low as feasible to harvest as many of the shorter spikes possible. However, the short standing stubble reduces protection from soil erosion by wind and soil water evaporation. The wind profile above the soil surface is significantly influenced by standing stubble height, with wind velocity at the soil surface increasing as stubble height decreases. Increasing the wind velocity at the soil surface is expected to increase potential for soil erosion and water evaporation. The soil erosion impacts are important because soil erosion control measures are currently required to be in compliance with federal programs. Soil and water conservation are necessary to sustain productivity, profitability, and environmental quality in semiarid cropping systems.

APPROACH: A combination of field experimentation and simulation modeling was used. Three years of field data were collected at the CSU Horticulture Farm to determine stem height frequencies and distributions for a commonly used winter wheat cultivar (TAM 107) under different tillage practices. We used the relationship by Hagan and Armbrust to generate the relative friction velocities (RFV) for different stem heights and densities. Stem height and density effects on relative soil water evaporation were calculated using the PENFLUX algorithm for ET.

RESULTS: Average stem heights differed over time and with pre-plant tillage treatments, demonstrating that crop management interacts with weather to determine plant height. Distributions around the mean were approximately normal, permitting assessment of maximum cutting height that minimizes harvest losses. Analysis suggested that if wheat is cut no higher than 2/3 of the mean stem height that harvest losses will be negiligible. Stem height and frequency modify wind profiles above the canopy. Generally following the logrithmic wind profile law, displacement height increased with taller, sparse canopies, but roughness length increased with shorter, dense canopies. Wind speed above and below the canopy affects the friction velocity at the soil surface, or energy available for momentum transfer. These results were integrated into a figure that shows the relationship between optimal wheat cutting height and the effect on soil erosivity and water evaporation. Soil and water conservation up to 80% was achieved when stem area index was 0.1 or greater and cover was at least 80%. Particularly for dry years, use of a stripper-header may help minimize harvest losses while maintaining maximum stubble cover and height.

FUTURE PLANS: Results were presented at the 1996 American Society of Agronomy meetings. A journal article and Conservation Fact Sheet are now being prepared to formally present the work and aid in technology transfer of the work.

---

[1]USDA-ARS, Central Plains Research Station, Akron, CO 80720.

SCALING ANALYSIS OF INFILTRATION AT R-5 CATCHMENT

Huan Meng[1], J.A. Ramirez[1], J.D. Salas[1], L.R. Ahuja and J.A. Ascough II

PROBLEM: It has long been realized that surface infiltration is a combined result of several heterogeneous fields including rainfall, soil properties, vegetation, topography, etc. Many studies have revealed the scaling nature of some of these affecting fields. But little has been accomplished in the study of the scaling characteristics of infiltration process. Since scaling surpasses some traditional spatial analysis methods in its ability to systematically deal with the process under study from a scale perspective, we will focus our study on the scaling analysis of infiltration process and the impact of constant rainfall on infiltration in a small area - R-5 catchment in Oklahoma.

APPROACH: If a process is wide sense scaling, its moments and its indexing variables (scale) should obey log-log linearity relationship. Furthermore, if the slope of the regression line is a linear function of the order of moment, this process is called a simple scaling process while the process is multiscaling if such a linearity does not exist. Another parameter that characterizes a process is its spectrum. Scaling processes in nature are often observed having power law spectra. Moment-analysis was carried out on a set of steady state infiltration (SSI) data from R-5 catchment in Oklahoma to investigate its scaling characteristics. The power law relationship of spectrum frequency was also examined. For the study of transient infiltration (TI), a Green-Ampt infiltration model was developed to compute TI rate. The arithmetic means of TI at each time step were calculated at seven scales and up to the third moment of these averages were computed at each scale. The impact of rainfall rate on scaling properties of infiltration was then evaluated.

RESULTS: Experiments with different rainfall rates were designed to investigate the influence of rainfall on the scaling of TI. Some conclusions drawn from the moment and spectrum analysis are as follows: a) Both SSI and TI rates at any moment are multiscaling; b) Slope of TI moment decreases and shows stronger multiscaling character with time; c) Maximum K_s is a threshold for rainfall, R. If $R \geq K_{s,max}$, slope of moment reaches SSI slope asymptotically. If $R < K_{s,max}$, slope still reaches stable, only at a value greater than SSI slope. At R-5, $K_{s,max} = 22.96$ cm/hr; d) Larger R facilitates faster slope decrease at the beginning of infiltration. But slopes under different R will eventually reach the same value and proceed to SSI slope at the same speed provided $R \geq K_{s,max}$. e) Spectra of both SSI and TI have power law relationship with frequency over two orders of magnitude.

FUTURE STUDIES: Based on the observed scaling characteristics of infiltration fields, random cascades infiltration models with appropriate generators and parameters will be developed for the estimation of spatial infiltration process. The impact of soil properties and spatially and temporally variant rainfall on the scaling properties of infiltration will also be explored.

---

[1]Department of Civil Engineering, Colorado State University.

DEVELOPMENT OF GPFARM SCIENCE SIMULATION MODULE

M.J. Shaffer, P.N.S. Bartling, M.K. Brodahl, L.R. Ahuja,
M.H. Nachabe, J.A. Ascough, B. Vandenberg, J.D. Hanson, D. Edmunds,
L.J. Wiles, G.S. McMaster, L. Deer-Ascough and H.J. Farahani

PROBLEM: A need exists for an integrated modeling package capable of simulating agricultural production systems in a whole farm setting using time and spatial scales suitable for the objectives of the GPFARM decision support system. Major components include crop and animal production, soil water and solute transport, nutrient cycling, evapotranspiration, tillage and residue effects, surface runoff and erosion, pesticide interactions, and weed management. The system model must be capable of simulating many different crops (including animals) in a multi-year rotational system for both irrigated and dryland conditions.

APPROACH: Existing technology and submodules were selected that are approximately suitable for the project objectives. Modifications and adaptations are being made to make these modules more appropriate for GPFARM. Simulation modules written in FORTRAN and Visual Basic have been integrated to operate from a control framework written in C++. The objective is to produce a suitable package capable of simulating soil-plant-animal processes for individual, but interacting management units in fields across a farm.

RESULTS: A pre-beta version of the GPFARM science simulation package was completed that combines FORTRAN and Visual Basic modules at the calculations level with an object-oriented C++ framework that manages the overall system integration. Refinements were made to the surface residue, water balance and chemical transport, soil erosion, weeds, and crop growth modules. A major revision to the animal module is in progress. Testing and refinements are continuing on individual modules and on the integrated package. The C++ framework was extended to support crop rotations over multiple years and future interactions between management units. Framework support was developed and refined for the input and output databases that link with the GPFARM DSS user interface. Database linkages were developed from the framework to the weeds module. Event framework implementation modules were developed that allow introduction of fixed-date events and events that are scheduled based on user-supplied rules and a defined state of the system.

FUTURE PLANS: The pre-beta version will be further evaluated and upgraded to beta versions suitable for testing and evaluation by a range of users. This includes development of a revised animal module, a whole-farm herd management system, and a revised forage production module, along with additional testing. Other future plans call for expansion of the nutrient module to include phosphorus and potassium, and possible additional of simulation modules for items such as insects and diseases. Framework enhancements will include accounting for animal movement across the farm and animal interactions with crop lands.

DEVELOPMENT OF GPFARM RULE-BASED EVENTS MODULE

M.J. Shaffer and M.K. Brodahl

PROBLEM: Most agricultural operations are run according to guidelines or rules that are established by each producer and are specific for a particular farm. To make effective use of emerging technology, producers and their crop consultants need to enter these rules into computerized decision support systems and then modify the rules as required. This dynamic linkage between the actual farming system and the computer is essential for representative feedback from the decision support systems.

APPROACH: We are developing a comprehensive rule-based management system for agricultural decision support systems that allows simulated management events to occur in response to producer-defined rules and to changes in the soil-crop system over time and space. Existing attempts at rule-based management involve limited extension of fixed management dates in response to environmental conditions, or involve rules for implementing limited management events such as fertilizer applications. Our system provides a simple, English-based rules language, a rules development editor, and software to parse and interpret these rules and provide linkages to application simulation software packages such as GPFARM, NLEAP, and others.

RESULTS: Considerable progress was made on the overall rule-based system. A rules editor was developed using Visual C++ that assists the user in developing the rules script needed to operate the interpreter package. The interpreter contains a parser program that translates the rules syntax into queries made to the simulation code and to operators within the interpreter, and then generates events string commands useable by an events initiator in the application program. The initiator then translates these strings into management events recognized by the simulation code. Rules were developed for wheat-corn-fallow and wheat-fallow rotations on a test farm in eastern Colorado, and then linked to the GPFARM simulation framework.

FUTURE PLANS: We will be interviewing producers in eastern Colorado and incorporating their on-farm management rules into our system. Based on these results and other work, refinements will be made in the rules editor to make it more easily used by producers and consultants, and in the interpreter code to allow it to handle more complex management systems. Eventually, we hope to develop a network of producers and consultants who use our rule-based system to evaluate current and alternate on-farm management systems.

SIMULATION OF REGIONAL SOIL NITROGEN GAS FLUXES USING NLEAP

M.J. Shaffer, C. Xu, M.K. Brodahl, R.F. Follett[1] and G. Hutchinson[1]

PROBLEM: Concern has increased regarding global climate change and the potential of health and environmental effects of changing atmospheric trace gas concentrations. Simulating emissions of nitrogen gases from soils as a function of soil properties, climate, crop production, and management practice can be important in understanding the role of terrestrial ecosystems in global climate change, in assessing environmental impact of agricultural production, and in determining natural resource use and management strategies.

APPROACH: The primary tasks of the project are to (1) extend the NLEAP denitrification submodel and related submodels to provide estimates of emissions of individual soil nitrogen gas pool components (e.g., N_2, N_2O, and NO_x), (2) calibrate and validate the NLEAP gas model using a range of data sets from local field experiments and across the United States, and (3) demonstrate the utility of using the NLEAP gas model in conjunction with a Geographical Information System (GIS) to estimate soil emissions of N_2, N_2O, and NO_x gases. Emphasis will be placed on the identification and simulation of cropping practices that minimize the emissions of N_2O and NO_x gases from soils.

RESULTS: Nitrification and denitrificaiton submodels of NLEAP were modified to simulate daily N_2O emission rates. During nitrification, the amount of N_2O emitted correlates with the amount of nitrifiable N in soils. In the denitrification submodel, the process of denitrification was driven by a term for rainfall and irrigation events, and by a second term for periods between events. Both terms are a function of several driving variables. A field experiment to calibrate parameters of the NLEAP gas model was conducted on an Ulm clay loam at the Colorado State University Agriculture Research Development and Education Center (ARDEC). To test the response of N_2O emissions to variations of relevant parameters, an on-farm experiment was conducted on a Valent sand soil with four swine effluent application treatments located in the south west of Yuma county, Colorado. The decline of N_2O emission rates during the growing season was related to soil nitrogen content. The behavior of N_2O emissions within the decline corresponded to soil moisture content. The highest emission rates occurred on the second day after swine effluent application. The statistical comparison of field measured and model simulated values of N_2O emission rates suggested that the trends and magnitudes of simulated nitrogen gas using the modified NLEAP model were consistent with results obtained from the field experiments.

FUTURE PLANS: The research will emphasize simulation and field experiments of N_2O emissions on variable nitrogen treatments, animal manure applications, tillage treatments, and irrigation management under different soil types.

---

[1]USDA-ARS, Soil, Plant, Nutrient Research Unit, Fort Collins, CO.

DEVELOPMENT AND ENHANCEMENT OF SUBMODELS FOR CROP-WEED INTERACTIONS, SURFACE RESIDUE DECOMPOSITION, AND MINERALIZATION OF SOIL ORGANIC MATTER

M.J. Shaffer, C. Xu, M. Vigil[1], R. Waskom[2] and R.M. Aiken[1]

PROBLEM: Development of research models such as RZWQM, NTRM-MS, and our 2-d models, as well as work with application models such as NLEAP and GPFARM has identified knowledge gaps that need additional basic research. Crop-weed interactions, surface residue decomposition, and mineralization pools of soil organic matter are topics where additional field data and model development are needed.

APPROACH: Field plots have been established at CSU's ARDEC, USDA-ARS, Akron, CO, and with farm cooperators. We will obtain detailed quantitative information on how surface residues decay as a function of the high spatial and temporal variability of the micro-climate that exists near the soil surface, including the transfer of standing dead to flat-lying residues.

RESULTS: Plot studies were completed at ARDEC (3 years of data) involving proso millet invasion of corn and show that both millet and corn yields are significantly reduced relative to monocultures of the same crops. This has occurred both in the fertilized and unfertilized treatments. Spatial variability of soil NO3-N content at the 0-1 foot depth was affected by N application as well as crop type. A comprehensive surface residue decomposition model has been assembled for use in GPFARM that simulates decay of standing dead and flat-lying residues, as well as nutrient transformations of mineral N on the soil surface. Soil N mineralization results from ARDEC and from farm fields have shown that rate of mineralization of soil organic matter is a strong function of recent management history. Field results after 3 years (1996) for the non-manured farm field showed the same total biomass production as the manured treatment, but the nitrogen contents of the corn grain and stover were both statistically lower than with the manured treatment.

FUTURE PLANS: The farm field and plot studies will be continued for several years so that sufficient annual data sets can be collected to allow adequate model development and testing. The NTRM-MS model will be expanded to include several crops and associated weed species. The soil organic matter study will test the feasibility of using the autoclave method (or a related lab. method) to analyze samples for the N zero pool.

---

[1]USDA-ARS, Akron, CO.

[2]Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO.

NLEAP TECHNOLOGY TRANSFER

M.J. Shaffer, M.K. Brodahl, P.N.S. Bartling, R.F. Follett and J. Hawes[1]

PROBLEM: Federal, state, and local agencies; ag-industry; and producers continue to be concerned about the urgent need to find ways to optimize on-farm production for profit and yet minimize adverse environmental impacts. Extension and educators recognize the need to bring these concerns into agricultural education. Models have been developed as tools for the development of mangement strategies, education, and the development of agency policy in agriculture for maintaining or improving the nation's soil and groundwater resources. A number of years of experience with NLEAP in different application settings has shown that NLEAP can be a useful tool.

APPROACH: We will continue to support and promote the use of the NLEAP model for a variety of applications and users. We will cooperate in the development of these strategies and track their effectiveness.

RESULTS: The NLEAP model is one of 5 water quality models adopted for use by the U.S. Natural Resource Conservation Service (NRCS). The NRCS NLEAP workbook and training files developed in cooperation with the NRCS have been completed, and will be available to NRCS personnel, as well as the public, over the Internet. The Idaho NRCS is using NLEAP as well as the other water quality models in the development of a mandated water quality improvement plan. In cooperation with J. Hawes, the national NRCS water quality model coordinator, this application is being used as a NRCS pilot project for investigating and establishing the agency's strategy for using models to address the application needs of state and field offices. We have provided technical expertise and training in this effort. Changes have been made to NLEAP simulation software for the CRADA with J.R. Simplot Company. Simplot wants to bring the NLEAP simulation technology into a Simplot software product dealing with fertilizer recommendations and precision farming. We continue to provide NLEAP model and application training and technical support to federal and university researchers and government agency personnel. In addition, we have used the model in a workshop hosted by Colorado State University extension and the NRCS Water Quality Project in the San Luis Valley to educate the local agricultural community on agriculture-water quality issues and present tools that they might use to address these issues in their operations.

FUTURE PLANS: We will continue to develop new technology transfer strategies. We will be working with the NRCS in the development of a web site that provides access to the NLEAP model customized by regions within the United States. Wc will continue to cooperate with the NRCS in refining methods for improved use of the model in addressing NRCS water quality issues. NLEAP ARS training courses will continue to be provided on a bi-annual basis.

---

[1]NRCS, State Office, Richmond, VA.

APPLICATION OF THE NLEAP MODEL TO REGIONAL NITRATE LEACHING IN NORTHEASTERN COLORADO

M.J. Shaffer, M.D. Hall[1], R.M. Waskom[2], J. Boyd[2], R. Schierer[3], D. DuBois[4] and D. Wagner[5]

PROBLEM: High levels of nitrate-Nitrogen (NO_3-N) in drinking water supplies pose health risks to humans and livestock. NO_3-N in and derived from fertilizers and manures applied to croplands can be moved into underlying aquifers. This nonpoint NO_3-N pollution is prevalent in areas with alluvial aquifers where aquifers tend to be shallow and soil profiles contain coarse textured soils. Farm management of nitrogen and water needs to be carefully considered on areas vulnerable to NO_3-N leaching.

APPROACH: Mechanistic modeling, Geographic Information System (GIS) technology, and field research have been combined to address NO_3-N leaching in an area in northeastern Colorado where irrigated agriculture occurs over the shallow South Platte River alluvial aquifer. Groundwater modeling was used in conjunction with NLEAP simulations to help clarify the processes contributing to nitrate hot spot stability and enable long term simulation of the effects of BMP implementation on aquifer water quality. Data collected from a manured field site near Lucern, CO were used in conjunction with NLEAP simulations to gain a better understanding of how minealization of manures contributes to nitrate leaching.

RESULTS: NLEAP leaching simulations combined with groundwater simulations using MODFLOW and MT3D and GRASS GIS indicated that the location and apparent stability of ground water nitrate hot spots in Weld County near Greeley, CO are satisfactorily explained by the spatial variability of surface management, spatial variations in system physical properties, and saturated ground water transport processes. Distribution of animal waste and extensive pumping of ground water were identified as key factors controlling spatial distribution of ground water nitrate concentrations. Results from the manured versus non-manured field site indicated that nitrogen stress on the zero N application treatment was beginning after three years, although yields were not yet impacted.

FUTURE PLANS: The manured field site will continue to be monitored and studied in an effort to obtain a long-term data set for mineralization of soil-applied beef manure. With the calibrated NLEAP/groundwater simulation system now constructed and tested, long-term simulations of BMPs can be conducted to estimate resulting impacts on NO_3-N concentrations in the ground water.

---

[1]Earth Resources Dept., Colorado State University, Fort Collins, CO.
[2] Dept. of Soil and Crop Sciences, Colorado State University, Fort Collins, CO.
[3]NRCS, Lakewood, CO.
[4]North Front Range Water Quality Planning Assoc.
[5]Dept. of Chemical and Bioresource Engineering, Colorado State University, Fort Collins, CO.

CONTROL OF NITROGEN PARTITIONING IN PERENNIAL GRASSES FROM ECOSYSTEMS WITH LIMITED NUTRIENT SUPPLY

R. Howard Skinner and Jon D. Hanson

PROBLEM: Experiments in controlled environments have suggested that more N is supplied in the xylem to shoots than can be used for shoot growth. Excess N is recycled back to the root for utilization in root production. The implication is that N partitioning is controlled by shoot utilization rather than by the root demand. These experiments are generally conducted, however, under conditions where root:shoot ratios are low and most of the N is partitioned to the shoot. This study will address the question of whether or not N recirculation occurs in range grasses growing under filed like conditions where root:shoot ratios are high and where much more of the total N is partitioned to roots.

APPROACH: Nitrogen recycling was investigated in blue grama (*Bouteloua gracilis*) growing at the Central Plains Experimental Range (CPER). Intact plant and soil cores were collected in 1995 and 1996 from CPER before spring growth had commenced and placed outdoors at the Agricultural Engineering Research Center (AERC) in Fort Collins. Harvests at AERC occurred on 19/20 June and 11 July 1995, and on 21 May and 11 June 1996. Companion harvests at CPER were made within one week of the harvests at AERC. Plants were divided into green shoots, stubble, and roots. Precipitation was recorded and pots were weighed periodically to determine evapotranspiration. Xylem sap was collected using a pressure chamber. Total N transport to the shoot was calculated by multiplying xylem N concentration by cumulative transpiration. N recycling was determined by comparing N transport in the xylem stream with shoot N accumulation rate. Results from CPER and AERC were compared to determine if removing plants from the field in intact soil cores affected growth and assimilate partitioning.

RESULTS: Xylem [N] at AERC was 0.084 mg ml^{-1} and N delivery to the shoot was 4.91 mg pot^{-1} d^{-1}. Shoot N accumulation was only 0.55 mg pot^{-1} d^{-1}, however, meaning 89% of the N delivered to shoots was available for recycling back to roots. The proportion of N being recycled in this slow-growing perennial was greater than that usually reported in the literature for seedling grown in controlled environment experiments. Combined across years and harvests, soil NH_4 levels in the cores at AERC were higher than in fresh cores collected from CPER (10 vs. 6 ppm, respectively). Soil NO_3 concentrations were low at both sites ($\approx$ 2 ppm). Increased NH_4 concentration at AERC was associated with a 23% increase in root weight compared with CPER ($P = 0.01$). A trend towards increased shoot weight was observed as well ($P = 0.12$). No relationship was found, however, between NH_4 and relative growth rate during the three-week growth period.

FUTURE PLANS: The experiments have been completed. Results will be published in 1997.

ROOT DISTRIBUTION UNDER ALTERNATE FURROW IRRIGATION

R. Howard Skinner, Jon D. Hanson and J.G. Benjamin[1]

PROBLEM: Alternated furrow irrigation of corn, with fertilizer placement in the non-irrigated furrow, provides a potential means of reducing nitrate leaching and groundwater contamination. Lack of root growth in the non-irrigated furrow, however, may limit N uptake. Separating fertilizer from the water supply may also reduce N uptake and plant growth because N supply to the root system in high productivity systems relies heavily on mass-flow transport in the soil solution. Several studies have shown that roots tend to proliferate in areas where water and/or nutrients are found in abundance, however, the effects of spatially separating water and nutrients withing the soil profile on root distribution have not been investigated.

APPROACH: Water and N were applied in a 2x2 factorial with every furrow vs. Alternate furrow irrigation, and furrow vs. Row fertilizer placement. Corn roots and shoot were sampled four times during each of two growing seasons, a V6-V9, V12-V16, R1 and R5-R6 in plots fertilized with ^{15}N-labeled fertilizer. Soil cores for root distribution, root nitrogen concentration, and soil water and nitrate determinations were taken in 30 cm increments to a depth of 120 cm from a 3 x 3 sampling grid centered over single corn plants which were harvested for shoot biomass and N content.

RESULTS: Two years data have now been collected. Maximum root biomass was observed at the R1 growth state. At R1 the main effects for irrigation treatment and fertilizer placement were not significant. Fertilizer by irrigation interactions affected root distribution but not total root biomass. When the fertilized furrow was not irrigated, 19% of the roots were in the fertilized furrow, 16% were in the irrigated but non-fertilized furrow, and 65% were beneath the row. Adding water to the fertilized furrow increased its percentage of the total biomass to 25% at the expense of the non-fertilized furrow (13%) and row (62%). The greatest redistribution of root growth occurred under alternate furrow irrigation when fertilizer was placed in the row. With this treatment 28% of the roots were found in the dry furrow, 10% in the wet furrow, and 62% in the row. Under every furrow irrigation and row fertilizer and row fertilizer placement, 72% of the roots were beneath the row. The remainder were distributed evenly between the two furrows. Plant N content is being analyzed to determine the effect of redistribution of root growth on fertilizer uptake.

FUTURE PLANS: All samples have been collected and data analysis will be completed in 1997. We will begin writing up results for publication during the coming year.

---

[1]USDA-ARS, Central Plains Research Station, Akron, CO.

CARBON AND NITROGEN REMOBILIZATION FOLLOWING DEFOLIATION

R. Howard Skinner, Jack A. Morgan[1] and Jon D. Hanson

PROBLEM: Following defoliation, both photosynthesis and N uptake can cease or be greatly reduced for a period of time. Initial shoot regrowth then depends on reserve N and C stored in root and crown tissue. We are interested in determining the relative importance of stored C and N in the regrowth process, which specific reserves are remobilized, how soil N concentration and atmospheric CO_2 affect reserve remobilization, and how the re-establishment of root:shoot ratio following defoliation can best be modeled.

APPROACH: A forage legume (alfalfa), C_3 grass (western wheatgrass), and C_4 grass (blue grama) were grown in growth chambers with two atmospheric CO_2 concentrations and tow soil N concentrations to provide a range of C and N storage levels in crowns and roots, as well as a range or external supply conditions for regrowth. Four growth chamber experiments will be conducted (two at ambient and two at elevated CO_2). Following defoliation, sequential harvests were mad at 0, 4, 7, 10, and 20 d, and plants separated into root, crown and regrowth tissue. Total dry weight was determined for each tissue, and N pools were partitioned into buffer-insoluble proteins, buffer-soluble proteins, and low molecular weight N compounds (amino acids, NO_3, etc.). Carbon was partitioned into structural dry matter, water soluble carbohydrates, and starch. Nitrogen and carbon remobilization and uptake were determined by changes in the respective pool sizes of each tissue. Results will be compared with several root:shoot partitioning models to determine which best describes the regrowth process.

RESULTS: All harvests have been completed and about /34 of the samples have been partitioned and analyzed for the various C and N pools. Regrowth was strongly, and negatively, correlated with whole plant relative growth rate during the first 4 d after defoliation. Thus, regrowth was greatest in plants that were able to quickly and completely shut down partitioning to crowns and roots. Based on an incomplete data set, it appears that carbohydrate concentration was not related to subsequent regrowth, nor was there a correlation between C or N remobilization and regrowth. No net N remobilization was detected in low N treatments which most closely resemble natural range conditions. Elevated CO_2 improved the ability of N stressed plants to continue taking up N immediately following defoliation. Nitrogen remobilization appears to be of little importance for regrowth following defoliation under current range conditions and will be of even less importance as atmospheric CO_2 increases.

FUTURE PLANS: All C and N partitioning and analysis will be completed in 1997. We will also begin writing the results for publication.

---

[1]USDA-ARS, Rangeland Resources Research Unit, Fort Collins, CO.

GREAT PLAINS SYSTEMS RESEARCH UNIT

Publications

Ahuja, L.R., Q.L. Ma, K.W. Rojas, J.J.T.I. Boesten, and H.J. Farahani. 1996. A field test of Root Zone Water Quality Model-pesticide and bromide behavior. Pestic. Sci. Sci., 48:101-108.

Aiken, R.M. and A.J.M. Smucker. 1996. Root system regulation of whole plant growth. Annual Review Phytopathol., 34:325-346.

Aiken, R.M., G.S. McMaster, and D.C. Nielsen. 1996. Optimal wheat cutting height for grain harvest and conserving soil and water. Agronomy Abstracts, p. 19.

Aiken, R.M., H.J. Farahani, and G.N. Flerschinger. 1996. Modeling residue cover and architecture effects on evaporation and soil temperature. Proceedings of 26th Annual Crop Simulation Workshop. April 9-11, Fort Collins, CO. p.3.

Aiken, R.M., G.N. Flerschinger, H.J. Farahani, and K.E. Johnson. Accepted, November 1996. Energy balance simulation for surace soil and residue temperatures with incomplete cover. Agronomy Journal.

Benjamin, J.G., L.R. Ahuja, and R.R. Allmaras. 1996. Modeling corn rooting patterns and their effects on water uptake and nitrate leaching. Plant and Soil, 179:223-232.

Benjamin, J.G., L. R. Ahuja, L. K. Porter, and H.R. Duke. 1996. Nitrogen leaching with alternate and every furrow irrigation and fertilizer bands. Agronomy Abstracts, p. 277.

Boyd, J. 1996. Evaluation of management practices for reducing nitrate leaching using field studies and the NLEAP model. M.S. Thesis, Colorado State University, Department of Soil and Crop Sciences, Fort Collins, CO. 120 pp.

Cole, V.C., C. Cerri, K. Minami, A. Mosier, N. Rosenberg, and D. Sauerbeck. 1996. Agricultural options for mitigation of greenhouse gas emissions, Chapter 23. In: Climate Change 1995 Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses Second Assessment Report Intergovernmental Panel on Climate Change. Eds: R. Watson, M.C. Zinyowera, and R.H. Moss. Cambridge Press.

Dabney, Seth M., L.D. Meyer, G.H. Dunn, G.R. Foster, and C.V. Alonso. 1996. Stiff grass hedges a vegetative alternative for sediment control. Federal Interagency Sedimentation Conference Proceedings. March 10.

Delgado, J.A., M.K. Brodahl, M.J. Shaffer, R.F. Follett, and J.L. Sharkoff. 1996. A list of

definitions to consider when using the NLEAP model to evalute N management pratices in soils containing coarse fragments. NLEAP FACTS sheet 5/96. USDA-ARS, Fort Collins, CO.

Dunan, C.M., L.J. Wiles, R.L. Anderson, P. Westra. 1996. A new approach to modeling weed population dynamics in crop rotations. Weed Sci. Soc. of Am. Abstr. 36:82.

Dunn, G.H. and S.M. Dabney. 1996. Modulus of elasticity and moment of inertia of grass hedge stems. Trans. ASAE Vol. 39(3):947-952.

Elliott, E.T., K. Paustian, G.A. Peterson, C.V. Cole, and K. Killian. 1996. Regional projections of carbon dynamics with global change in the central U.S. interactive effects of management, climate, and elevated carbon dioxide. p. 259-270. IN: Toward and Integrated Regional Research Program on Global Change and the Nation's Major Grasslands. W.E. Easterling (ed.), Univ. of Nebraska, Lincoln, NE. GPRC 96-01.P. 259-270.

Enns, R.M., R.M. Bourdon, J.S. Brinks, B.L. Golden, J.D. Hanson, and B.B. Baker. 1996. Simulation of diverse biological types I:Genetic parameters and relationships between EPD and physilological breeding values. Journal Animal Science 74(Suppl. 1):113. (Abstract).

Enns, R.M., R.M. Bourdon, J.S. Brinks, B.L. Golden, J.D. Hanson, and B.B. Baker. 1996. Simulation of diverse biological types II: Bred complementarity. Journal Animal Science 74(Suppl. 1):114. (Abstract).

Faber, Brenda G., and W. Wallace. Active Response GIS: A collaborative modeling tool for environmental decision making. Eco-Informa '96-Global Networks for Environmental Information. Lake Buena Vista, FL. Nov. 1996. ERIM:73-78

Faber, Brenda G., W. Wallace, and R. Miller. Collaborative modeling for environmental decision making. Proc. of the GIS '96 Tenth Annual Symposium on Geographic Information Syst. Vancouver, B.C. March 1996, GIS World, Inc.

Farahani, H.J., W.C. Bausch, R.M. Aiken, and L.R. Ahuja. 1996. Evapotranspiration modeling in system-wide agricultural models. Proceedings of the International Conference on evapotranspiration and irrigation scheduling. ASAE and IA. Nov. 3-6, San Antonio, TX. p. 1165.

Farahani, M.J. and L.R. Ahuja. 1996. Evapotranspiration modeling of partial canopy/residue covered fields. Tranactions of the ASAE. 39(6):2051-2064.

Farahani, H.J., G.A. Peterson, D.G. Westfall, L.A. Sherrod, L.R. Ahuja. 1996. The ineffeciency of summer fallow in dryland/no-till cropping systems. Agronomy Abstracts, p. 295.

Hall, M. 1996. Simulation of nitrates in a regional subsurface system: Linking surface management

with ground water quality. PhD Dissertation, Colorado State University, Department of Earth Sciences, Fort Collins, CO. 165 pp.

Hanson, J.D. 1996. The generic crop production model for RZWQM. 26th Annual Crop Simulation Workshop. April 9-11, Fort Collins, CO. (Abstract).

Hanson, J.D., D.B. Palic, G.H. Dunn, and E.F. Kelly. 1996. Spatial analysis of various soil properties in a semiarid rangeland. Geocarto International 11(3):93-98.

Hanson, J.D. 1996. Spatial analysis of various soil and plant parameters. Abstracts of Papers for the 49th Annual Meeting of the Society for Range Management. (Invited) (Abstract).

Harrell, D.M., W.W. Wilhelm, and G.S. McMaster. 1996. SCALES 2.0: Expanded computer program converts among development stage scales for corn and small grains. Agronomy Abstracts, p. 130-131.

Kratz, T.K., J.J. Magnuson, P. Bayley, B.J. Benson, C. W. Berish, C. Bledsoe, E.R. Blood, C.J. Bowser, S.R. Carpenter, G.L. Cunningham, R. Dahlgren, T.M. Frost, J. Halfpenny, J.D. Hanson, D. Heisey, R. Inauye, D. Kaufman, A. McKee, and J. Yarie. 1996. Temporal and spatial variability as neglected ecosystem properties: Lessons learned from 12 North American ecosystems. In: Evaluating and monitoring the health of Large-Scale Ecosystems. Proceedings.

Logsdon, S.D., M.H. Nachabe, and L.R. Ahuja. 1996. Macropore modeling: State of Science. Proc. ARS Workshop on "Real World" Infiltration. CO Water Resour. Res. Inst. Information. Series #86 p. 217-227.

McMaster, G.S. 1996. (Invited Paper) Phenology, development, and growth of the wheat (*Triticum aestivum L.*) shoot apex: A review. Advances in Agronomy, 59:63-118

McMaster, G.S., and W.W. Wilhelm. 1996. Should we use soil rather than air temperature to predict wheat (*Triticum aestivum L.*) phenology? Agronomy Abstracts, p. 13.

McMaster, G.S., and W.W. Wilhelm. ARS peer-review. Is using soil temperature better than air temperature for predicting winter wheat (*Triticum aestivum L.*) phenology? Field Crops Research.

McMaster, G.S., and W.W. Wilhelm. Accepted 5/9/96. Conservation compliance credit for winter wheat fall biomass and implications for grain production. Journal Of Soil And Water Conservation.

McMaster, G.S. and W.W. Wilhelm. Accepted 12/19/1996. Growing degree-days: One equation, two interpretations. Agricultural and Forest Metheorology.

McMaster, G.S, D.R. LeCain, J.A. Morgan, L. Aiguo, and D.L. Hendrix. ARS peer-review. CO_2, photosynthesis, leaf carbohydrates, growth, and development of spring wheat. Canadian Journal of

Plant Sciences.

McMaster, G.S., J.A. Morgan, D.R. LeCain, and L. Aiguo. Accepted. Environment and the phyllochron. In: GCTE Wheat
Network Experimental Synthesis publication.

McMaster, G.S. and W.W. Wilhelm. 1996. Should we use soil rather than air temperature to predict wheat phenology? Proceedings of the 26th Annual Crop Simulation Workshop. April 9-11, Fort Collins, CO. p. 15.

Ma, Q.L., L.R. Ahuja, R.D. Wauchope, J.G. Benjamin, and B. Burgoa. 1996. Comparison of instantaneous equilibrium and equilibrium-kinetic sorption models for simulating simultaneous leaching and runoff of pesticides. Soil Science, 161:646-655.

Matherell, A.K., C.A. Cambardella, W.J. Parton, G.A. Peterson, D.A. Harding, and C.V. Cole. 1995. Simulation of soil organic matter dynamics in dryland winter wheat-fallow cropping systems. p. 259-270. IN: Soil Management and Greenhouse Effect. Lal, R., J. Kimble, E. Levine, and B.A. Stewart. (eds.). Davis Publishers, Boca Raton, FL.

Mattakali, N.M., E.T. Engman, L.R. Ahuja, K. Johnson, T.J. Jackson. 1996. Spatial variability of saturated soil hydraulic conductivity derived from remotely-sensed data. Ch. 13 in Scaling Up in Hydrology Using Remote Sensing, J.B. Stewart et al. (eds.). John Wiley, New York.

Mattakali, N.M., E.T. Engman, L.R. Ahuja, and T.J. Jackson. 1995. Estimating soil properties from microwave measurements of soil moisture. Conference on Remote Sensing for Agriculture, Forestry, and Natural Resources. Sept. 26-28, 1995. Paris, France.

Meng, H., J.A. Rameriz, J.D. Salas, and L.R. Ahuja. 1996. On the scaling characteristics of infiltration process. Abstract AGU Winter Meetings, Dec. 16-20, 1996, San Francisco, CA.

Nachabe, M.H., and L.R. Ahuja. 1996. Quasi-analytical solution for predicting the redistribution of surface-applied chemicals. Trans. ASAE 39:1659-1664.

Nassar, I.N., J.G. Benjamin, and R. Horton. 1996. Thermally induced water movement in uniform clayey soil. Soil Sci. 161:471-479.

Nielsen, D., G.A. Peterson, R. Anderson, V. Ferreira, et al. 1996. Growing annual legumes in dryland agroecosystems in northeastern Colo. Agronomy Abstracts p. 283.

Nielsen, D., G.A. Peterson, R. Anderson, V. Ferreira, W. Shawcroft, and K. Remington. 1996. Estimating corn yields from precipitation records. Cons. Tillage Fact Sheet 2-96. USDA/ARS and USDA/NRCS, Akron, CO.

Nokes, S.E., F.M. Landa, and J.D. Hanson. 1996. Evaluation of the crop growth component of the Root Zone Water Quality Model for corn in Ohio. ASAE 39(3):1177-1184.

Peterson, G.A., D.G. Westfall, L. Sherrod, R. Kolberg, and D. Poss. 1996. Sustainable dryland agroecosystem management. Technical Bulletin TB96-1. Agricultural Experimentation Station, Colorado State University, Fort Collins, CO.

Shaffer, M.J., M.D. Hall, B.K. Wylie, and D.G. Wagner. 1996. NLEAP/GIS approach for indentifying and mitigating regional NO3-N leaching. Chapter 17, In: Application of GIS to the Modeling of Non-point Source Pollutants in the Vadose Zone. SSSA Special Publication, American Society of Agronomy, Madison, WI.

Shaffer, M.J., and C. Xu. 1996. Simulation of regional soil nitrogen gas fluxes using NLEAP. Global Climate Change Report,
USDA-ARS, Fort Collins, CO.

Shaffer, M.J., B.K. Wylie, and M.D. Hall. 1996. Identification and mitigation of nitrate leaching hot spots using NLEAP-GIS technology. Journal of Contaminant Hydrology. 20:253-263.

Shaffer, M.J., C. Xu, and M.K. Brodahl. 1996. Simulating crop residue decay and redistribution on the soil surface. Agronomy Abstracts, p. 291.

Sherrod, L.A., G.A. Peterson, D.G. Westfall. 1996. No-till rotational residue dynamics across a ET gradient. Agronomy Abstracts. p. 282.

Singh, P., R.S. Kanwar, K.E. Johnson, and L.R. Ahuja. 1996. Calibration and evaluation of subsurface drainage component of RZWQM V.2.5. J. Environ. Qual. 25:56-63.

Skinner, R.H. 1996. Response of Bemisia argentifolii (Homoptera:Aleyrodidae) to water and nutrient stressed cotton. Environ. Entomol. 25:401-406.

Skinner, R.H., C.J. Nelson, J.H. Coutts. 1996. Tall fescue growth after paraquat application to elongating or mature leaves. Agronomy Journal. 88:49-53.

Skinner, R.H., J.D. Hanson, 1996. Nitrogen circulation and partitioning in blue grama. Agronomy Abstracts. p. 102.

Skinner, R.H., J.D. Hanson, and J.G. Benjamin. 1996. Effects of water and nitrogen placement on corn root distribution and nitrate leaching. 5th International Society of Root Research Symposium, July 14-18, Clemson, SC.

Skinner, R.H. 1996. Leaf temperature effects on *Bemisia argentifolii* (Homoptera: Aleyrodidae) oviposition. Environ. Entomol. 25:1371-1375.

Skinner, R.H., J.A. Morgan, and J.D. Hanson. Accepted 1997. Nitrogen and CO_2 effects on remobilization of root and crown reserves for regrowth following defoliation. Proceedings XVIII International Grassland Congress.

Skinner, R.H., and J.D. Hanson. 1996. Nitrogen circulation and partitioning in blue grama. Agronomy Abstracts, p. 102.

Skinner, R.H., J.D. Hanson, and J.A. Morgan. 1996. Substrate mobility and the modeling of carbon and nitrogen partitioning following defoliation. 26th Annual Crop Simulation Workshop, April 9-11, Fort Collins, CO.

Timlin, D.J., R.D. Williams, and L.R. Ahuja. 1996. Soil hydraulic parameters for regional scale application of mechanistic models. In application of GIS to the Modeling of non-point source pollutants in the Vedose Zone. SSSA Spec. Public. #48. Soil Sci. Soc. of Am., Madison, WI.

Timlin, D.J., W.J. Rawls, R.D. Williams, and L.R. Ahuja. 1996. Indirect estimation of hydraulic conductivity and its spatial distribution. Proc. ARS Workshop on "Real World" Infiltration. CO Water Resour. Res. Inst. Information. Series #86 , p.76-90.

Wiles, L.J., R.P. King, E.E. Schweizer, D.W. Lybecker, and S.M. Swinton. 1996. General Weed Management Model. Agricultural Systems. 50:355-376.

Wiles, L.J., D.H. Barlin, E.E. Schweizer, H.R. Duke, and E.E. Whitt. 1996. A new soil sampler and elutriator for collecting and extracting weed seeds from soil. Weed Technology. 10:35-41.

Wiles, L.J. and E.E. Schweizer. 1996. Distribution of weed seed and seedling populations in commercial corn fields in Colorado. Weed Sci. Soc. Am. Abstr. 36:82.

Wilhelm, W.W. and G.S. McMaster. 1996. Spikelet and floret naming scheme for grasses with spike inflorescences. Crop Science, 36:1071-1073.

Wilhelm, W.W. and G.S. McMaster. 1996. Corn development: Sequence and timing of phenological events. Agronomy Abstracts, p. 12.

Williams, R.D., L.R. Ahuja, and D.J. Timlin. 1996. Estimating the soil water retention curve with soil bulk density and -33kPa value. Proc. ARS Workshop on "Real World" Infiltration. CO Water Resour. Res. Inst. Information. Series #86. p. 91-101.

Xu, C. and M.J. Shaffer. 1996. NLEAP simulation of nitrogen gas emissions. Agronomy Abstracts, p. 33.

RANGELAND RESOURCES RESEARCH UNIT

Gerald E. Schuman, Research Leader
High Plains Grasslands Research Station
8408 Hildreth Road
Cheyenne, WY 82009
TEL: (307) 772-2433
FAX: (307) 637-6124

INTERNET: gschuman@lamar.colostate.edu

TABLE OF CONTENTS

CRIS PROJECTS

5409-11210-001-00D	Physiological/genetic studies contributing towards a sustainable productive rangeland
5409-1210-001-02S	Responses of mycotrophic C_3 and C_4 rangeland grasses to atmospheric $C0_2$ and water
5409-11210-001-03R	Seed treatment and sagebrush seedling vigor
5409-11210-001-04S	Wildland shrub seed biology
5409-11210-001-05S	Responses of rangeland grasses to $C0_2$ and herbivory
5409-12130-001-00D	Management of alternatives for sustainable production of marginal croplands, disturbed land/rangelands
5409-12130-001-04S	Hydrologic assessment of rangelands using rainfall simulation
5409-12130-001-06R	The role of vesicular-arbuscular mycorrhizae on drought stress tolerance of big sagebrush
5409-31630-001-00D	Management and ecology of Great Plains rangelands for sustained animal production
5409-31630-002-05S	Rangeland management for sustained production in the Central Great Plains

These CRIS projects were rewritten in 1996 and have subsequently been replaced throughout the year.

MISSION STATEMENT

The research mission is to develop an understanding of the interrelations of the basic resources that comprise rangeland ecosystems. Research is directed toward the development of science and technology that contributes to sustainable and productive pasture and rangeland ecosystems in the Central Great Plains.

TECHNOLOGY TRANSFER

The Unit staff participated in the CPER Symposium where all research being accomplished on the CPER is highlighted in poster presentations by the many contributors from throughout the United States.

Dr.'s Hart and Bai attended the International meeting of the Society for Range Management in Wichita, KS and presented papers. Dr. Hart's presentation was invited.

Dr.'s Booth and Schuman presented seminars to the Plant, Soil and Insect Sciences Department at the University of Wyoming.

Numerous staff assisted in showing numerous groups of students around the High Plains Grasslands Research Station and explaining the research to them.

Pam Freeman and Dr. Hart presented guest lectures to several school classes.

Dr. Hart presented invited lectures at the Wyoming State Museum's lecture series ("Great Plains rangelands before European settlement") and at the kick-off for National Parks Week (Teddy Roosevelt-"Conservation in Our National Parks')

Dr. Hart was guest lecturer for two Colorado State University classes in the Rangeland Ecosystem Sciences Department.

Dr. Hart served on the selection committee for Range Ecologist position, Rangeland Ecosystems and Watershed Management Department, University of Wyoming

Dr.'s Hart, Schuman, and Morgan reviewed grant applications in CSREES Rangeland Grants (Hart), Abandoned Coal Mined Land Research Program and North Dakota Lignite Council (Schuman), and CSREES National Research Initiative (Morgan).

Unit staff participated in the Unit field day held at the Central Plains Experimental Range.

Several staff members judged science fairs at local elementary schools and also at the district level.

Unit staff participated in the ARS-NRCS Open House to highlight the NRCS Grazing Lands Technical Team that is co-located with the Unit at Cheyenne and to discuss cooperative efforts that are and will result from this cooperation.

Dr.'s Booth and Hart attended the Wyoming Section, Society for Range Management annual technical meeting.

Dr. Booth presented research summaries at the annual Abandoned Coal Mined Land Research Program seminar, to the Intermountain Conservation District's mine reclamation workshop, and met with the Wyoming Mining Association reclamation subcommittee.

Dr. Schuman, Gary Frasier, and Mary Ashby participated in a NRCS range health field evaluation at the Central Plains Experimental Range

Gary Frasier and Jean Reeder attended a Range Health planning workshop, Fort Collins, CO

Larry Griffith demonstrated the Cased Hole Punch Seeder to the Teachers Alliance Workshop, Laramie County Community College, Cheyenne, WY

Pam Freeman presented presentations at the Expanding Your Horizons Conference, Laramie County Community College, Cheyenne, WY

Dr. Morgan is a member of the Western Regional Coordinating Committee-9, "Improving Stress Resistance of Forages in the Western U.S." He discussed the Units research in that area with other state and federal scientists and planned future research at the annual meeting in Salt Lake City, UT.

Dr. Morgan chaired the Unit field day committee and was responsible for organizing the half-day Global Climate Change symposium that was part of the field day.

Dr. Morgan participated in the Career Days at Poudre Valley High School and discussed careers in agriculture.

Kathleen Peterson participated in Career Days at Laramie County Community College and exhibited the Unit display and had information on job opportunities for students and full-time positions available for all USDA agencies in Cheyenne.

Dr. Morgan participated in the workshop "Interactions between elevated CO_2 and water supply in grasslands" in Davos, Switzerland. He presented research findings on simulation modeling of plant growth responses to elevated CO_2 concentrations.

Mary Ashby hosted tours at the CPER for classes/groups from the Front Range Community College, Kansas Association of Biology Teachers, Wyoming Geographic Information Advisory Council, and Tribal Council Teachers.

Dr. Schuman was a Visiting Fellow in the Soil Science and Plant Nutrition Department, University of Western Australia for 6 months. He worked directly with faculty members in the area of rangeland health, land rehabilitation completion criteria, and with a mining company evaluating rehabilitation success and their general rehabilitation program.

Dr. Schuman presented invited keynote lecture at the International Conference on the Remediation and Management of Degraded Lands in Hong Kong.

Dr. Schuman presented two invited lectures at the workshop, "Restoration and Management of Mined Lands: Principles and Practices in Guangzhou, PRC.

Dr. Schuman presented a talk on the soil carbon and nitrogen balance at the Australian and New Zealand National Soils Conference in Melbourne, Vic. and also presented the talk at the Australian Soil Science Society-Western Branch seminar series, Perth, WA.

Dr. Schuman presented a talk on recent mined land reclamation advancements in the Great Plains, USA at the 3rd International and 2lst Annual Minerals Council of Australia Environmental Workshop in Newcastle, NSW.

Dr. Schuman presented "Reclamation of bentonite mined lands," at the American Society of Surface Mining and Reclamation and American Society of Agronomy joint session of the ASSMR conference in Knoxville, TN. This will also be published in the 2nd edition of the Reclamation of Drastically Disturbed Lands monograph to be published by ASA.

Dr. Hart attended ARS-NRCS workshop on decision-support tools, Fort Worth, TX. This workshop discussed the need for developing compatible decision-support tools within the two agencies.

MEASURING MOISTURE CONTENT OF SMALL SEEDS

D. Terrance Booth and Yuguang Bai[1]

PROBLEM: A precise determination of moisture content in seeds is fundamental to understanding early physiological processes. One difficulty encountered while measuring seed moisture is that water evaporates from hydrated seeds during weighing. This is particularly significant for small seeds because they have a large surface area to volume ratio.

APPROACH: Seeds of Wyoming big sagebrush (Artemisia tridentata Nutt. ssp. wyomingensis Beetle & Young) and tin capsules manufactured by LECO Corporation (St. Joseph, MI 49085), were used in this study. The capsules, which sell for about $36 per package of 100, are designed to hold powder or liquid samples by crimping the open end of the capsule before analysis. The standard capsule has a mean weight ± standard error (SE) of 179.040 ± 2.150 mg, and a volume of 0.25 ml. In our test, twenty sagebrush seeds were put into each capsule and the open end was folded twice and crimped with tweezers. Capsules containing sagebrush seeds were then placed above distilled water in a closed plastic box at 10°C, and the capsules retrieved after 0, 2, 4, 6, 8, 16, 24, 48, 120 and 360 hours. Open capsules were sealed immediately as described above. Weighing was done approximately 30 minutes after retrieval as well as after 24 hours of oven drying at 80°C. Capsules were opened during oven drying and re-sealed after removing from the oven. Four replications were used for each treatment.

RESULTS: The moisture content of seeds in open capsules increased rapidly after humidification. Seeds in sealed capsules did not absorb significant amounts of water in the first 5 days. Weighing takes just a few minutes; therefore, sealing hydrated seeds in tin capsules will prevent evaporation from seeds during handling. Aluminum volatile sample pans (Perkin-Elmer) which are specially designed for use in Differential Scanning Calorimetry, have also been used to obtain a stable weight of hydrated seeds. A crimping tool, called the volatile sample sealer accessory, is needed for sealing the pans. The pans cost about three times that of standard tin capsules and the accessory sells for about $1000. We found that it took less time to seal the capsule than to seal the pan. We recommend the use of the tin capsules, similar to the ones used in this study, for obtaining accurate weights of hydrated seeds.

FUTURE PLANS: This project is concluded and the information is being used in our other studies of sagebrush and other small seeds.

---

[1]Formerly, Dept. of Plant, Soil and Insect Sci., Univ. of Wyoming, Laramie, Wyo.

THE ESTABLISHMENT OF SAGEBRUSH PATCHES BY PUNCH PLANTING THROUGH FABRIC MULCH[1]

D.T. Booth

PROBLEM: The re-establishment of native shrubs on mined lands is a prerequisite for bond release to mining companies operating in Wyoming and other western states. Wyoming law states; "Except where a lesser density is justified from premining conditions, at least 20 percent of the eligible land shall be restored to shrub patches supporting an average density $\geq$ 1 shrub/m^2." To consistently establish shrub stands $\geq$ 1 shrub/m^2 may require cultural methods that substitute for the episodic weather patterns associated with periodic establishment of thick stands. Those involved in ecological restoration need innovative methods to create thick shrub patches at will.

APPROACH: The following cultural methods were compared for establishing sagebrush: 1. fabric mulch with no mulch, 2. polyacrylamide soil amendment with no amendment, and 3. Cased-Hole Punch Planting (CHPS) using 76 and 127-mm casings. These methods were compared to dropping seeds on the soil surface at the seed spot to simulate broadcasting (the standard seeding method for sagebrush). CHPS is a punch-planting technique in which a seed hole is punched into the soil and cased with plastic tubing which prevents soil from sloughing into the hole. The casing also projects above the soil surface to provide additional protection to seedlings. Plots were on top-soiled mine spoil at the Pathfinder Mine, Shirley Basin, Wyoming. The soil was rototilled and polyacrylamide was incorporated into the topsoil on half of the plots at the rate of 0.1 kg/m^2. Fabric mulch was then installed on half the plots to give equal combinations of mulch and polymer treatments. Seeding was done in November and December 1994, by filling the cased holes with 1-2 cc of vermiculite, followed by 3 pure live seeds in a starch pellet.

RESULTS: Seven percent of broadcast seed spots contained plants in November 1996. This compared to 39% for CHPS with 76-mm casings and 58% for CHPS with 127-mm casings. Average heights of sagebrush completing 2 growing seasons was 74, 111, and 138 mm for broadcast, 76-mm casings and 127-mm casings. Plants growing without fabric had an average height of 73 mm, those in fabric averaged 180 mm. The polymer had no significant effect on establishment or growth. Sagebrush seed was produced in the CHPS+fabric plots the second growing season. Sagebrush seed was not produced in the other plots.

FUTURE PLANS: Sagebrush seed quantity and quality will be compared among treatments for several years.

---

[1]Acknowledgments: Pathfinder Mining Corp. provided fenced plot sites and Western Polyacrylamide Inc. provided polymer and fabric mulch.

RANGELAND GARDENS - MEETING THE CHALLENGE OF THE NEXT CENTURY[1]

D.T. Booth and L.W. Griffith

PROBLEM: Agriculture consumes about 87% of the worlds fresh water. Rangeland gardens are a test of our ability to grow produce using only natural rainfall. If successful, this use of rangelands could mean an increase in sustainable food production and more management options for farmers and ranchers.

APPROACH: We tested a combination of 3 technologies; UV-resistant fabric mulch, polyacrylamide soil amendment, and the ARS-developed Cased-Hole Punch Seeder (CHPS). Production was compared with, and without fabric mulch, and in combination with 0.1 and 0.5 kg polymer/m^2 soil surface. The plots were seeded with CHPS or by hand. To hand plant through the fabric, holes were burned at appropriate intervals. There were 12 treatment combinations of fabric, seeding method, and polymer application rates. We seeded an early maturing variety of cantaloupe (Minnesota Midget), and a pickling cucumber (Miss Pickler) in the gardens. The fabric has a 5 year warranty. The life expectancy of the polymer is unknown. We amortized the cost of installing the gardens over 5 years, and extrapolated costs, yields, and profit to provide a rough estimate of potential profit and loss compared to rangeland forage production. The complete experiment was replicated at the High Plains Grasslands Research Station in Cheyenne, the Zimmerman Ranch near Pine Bluffs, WY, and the Univ. of Wyoming Research and Extension Center in Torrington, WY. The Pine Bluffs plots were on Conservation Reserve Program land that was withdrawn from the program in 1996.

RESULTS: Yields ranged from 0 to 31 kg/plot for cucumbers, and 0 to 19 kg/plot for cantaloupe, at Torrington and the Zimmerman Ranch. Plots at Cheyenne suffered hail damage and there was no harvest. Plants at Torrington appear water stressed. The greatest estimated profit from cantaloupe was from hand planting the seed through fabric where no polymer was used; for cucumbers it was from CHPS through fabric with 0.1 kg/m^2 of polymer. Besides providing a management option, farming with fabric contributes to long-term profitability by protecting the soil from wind and water erosion. Traditional uses of rangeland are for grazing and dryland hay production. Dryland hay returns about $215/ha ($87/acre). Rangeland gardens appear to have a potential return that exceeds that of forage production, and by a margin that may compensate for the greater risks involved in the production and marketing of perishable produce.

FUTURE PLANS: This project is concluded. However, we recommend further development and would welcome an opportunity to do that.

[1]Acknowledgments: Western Polyacrylamide Inc. provided the polymer and fabric mulch.

RANGELAND ALFALFA: GENETICS, PHYSIOLOGY & MANAGEMENT

J.A. Morgan, R.H. Hart, G.E. Schuman, R.H. Skinner[1], J.D. Hanson[1],
K.H. Asay[2] , and D.A. Johnson[2]

PROBLEM: Utilizing legumes in improved complementary pastures has the potential for improving forage quality and quantity for livestock production systems. One of the major problems in managing alfalfa is persistence. Considerable efforts have gone into understanding the physiological bases for persistence. However, little progress has been made applying that information in breeding and management applications other than in the adoption of harvesting or grazing practices that preserve metabolites for over-wintering.

APPROACH: Two field experiments were begun at the USDA-ARS High Plains Grassland Research Station in Cheyenne, WY in 1994. In a genetics study, 80 cultivars/accessions of alfalfa were transplanted and established into ten replicate blocks. These plants were grazed by sheep for seven weeks in July and August of both 1995 and 1996, and were evaluated in both years for persistence, spread, height, and development. In another study, two alfalfa varieties ('Spreador II' and 'WL 317') and two grass species ('Hycrest' Crested Wheatgrass and 'Bezoisky Select' Russian Wildrye) were seeded alternately in rows of variable width to evaluate optimum row spacing necessary to overcome water and nutrient competition, and the affect on persistence. In a growth chamber study, the contribution of belowground N and C reserves of alfalfa, western wheatgrass and blue grama to regrowth after defoliation was evaluated under variable N nutrition and ambient CO_2.

RESULTS: The grazing and competition phase of the study has been imposed for two years, following their establishment in 1994. Genotype/accession differences in spread have already been expressed in the grazed nursery, although differences in persistence have not. Similarly, the effects of row spacing on plant biomass production were evident in year one of the competition study, although stand density has been largely unaffected except for the most narrow spacing treatment in the study. In the growth chamber study, carbohydrate concentration in belowground organs was not related to subsequent regrowth of forages following defoliation, nor was there a correlation between carbohydrate or nitrogen remobilized from belowground root and crown tissues during regrowth. This latter finding suggests that regrowth of defoliated forages may not be simply related to pools of belowground C and N.

FUTURE PLANS: Treatments and management of the plots will continue in 1997. Grazing will continue on the genetics study, although grazing pressure may be increased to enhance the defoliation stress on the plants. In the competition study, monitoring of growth will continue. Select plants in different row spacings will be evaluated for belowground reserves by placing buckets over plants and harvesting etiolated growth. A growth chamber experiment will begin to evaluate how interactions of defoliation and CO_2 affect belowground C and N storage compounds and regrowth.

---

[1]Great Plains Systems Research, Ft Collins, CO; [2]USDA-ARS Forage & Range Res., Logan , UT

GLOBAL CHANGE AND IMPLICATIONS FOR RANGELANDS

J.A. Morgan, D.R. LeCain, J.J. Read[1], A.R. Mosier and H.W. Hunt[2]

PROBLEM: Atmospheric CO_2 concentrations have risen from 280 ppm in pre-industrial times to more than 350 ppm today, and are projected to continue rising well into the next century, with a doubling over present levels expected by mid- to late- 21st century. Global temperatures and precipitation patterns are projected to change at historically unprecedented rates in the next century. Virtually all ecosystems on the earth will be affected by these changes, so it is imperative that we understand these changes to prepare for them.

APPROACH: Data from growth chamber studies were subjected to statistical analysis and modeling exercises to understand how elevated CO_2 affected the physiology and growth of two important grasses of the shortgrass steppe, western wheatgrass (*Pascopyrum smithii*, C_3) and blue grama (*Bouteloua gracilis*, C_4). In another study, we investigated whether differences in the ability of C_4 grasses to respond to $C0_2$ might be dependent on their particular kind of C_4 metabolism. Some C_4 grasses are known to be more efficient that others, and we speculated that the less efficient types, of which blue grama is a member, might respond more to elevated CO_2 than others. In a new study, large open-top chambers were constructed at the Central Plains Experimental Range to investigate the effect of CO_2 enrichment on shortgrass steppe vegetation and soils in the field.

RESULTS: Statistical analysis revealed that photosynthesis, growth and water use efficiency of both grasses were stimulated by CO_2 concentrations twice present ambient concentrations, although concentrations of N, P, and K were generally reduced in tissues of CO_2-enriched plants. This dilution of plant minerals has been detected in other studies, and has been attributed to a depletion of soil nutrients and to alterations in plant metabolism (acclimation) that allow plants to adjust their allocation of resources. A modeling exercise indicated that for this study, the reduction in tissue N concentrations of CO_2-enriched grasses was due mostly to a reduction of available soil N. Analysis of the C_4 grass study did not support our hypothesis that the less efficient type of C_4 grasses responded more to CO_2 enrichment. It did, however, indicate that C_4 grasses have the capability to respond photosynthetically to CO_2, and as a result will sometimes accumulate carbohydrates at elevated CO_2 concentrations. In the field work, open-top chambers were built and tested for ability to maintain target CO_2 concentrations. Initial vegetation samples were taken in the different chamber locations to characterize the site before CO_2 fumigation begins in spring, 1997.

FUTURE PLANS: The biggest change for next year will be the open-top chamber study which will allow us for the first time to go to the field and observe how CO_2 enrichment affects shortgrass steppe vegetation and soils, and to begin to extrapolate that information to the landscape level. Modeling and growth chamber work will continue to investigate how CO_2 enrichment effects specific mechanisms like partitioning responses that are difficult to evaluate in the field.

---

[1]Australian National Univ., Canberra, Australia; [2]Dept. of Rangeland Ecosystem Science, CSU.

GRAZING AND CARBON EXCHANGE ON SEMI-ARID RANGELANDS

J.A. Morgan, D.R. LeCain, G.E. Schuman, J.D. Reeder and R.H. Hart

PROBLEM: How to manage rangeland for economic gain while preserving our native grasslands is a major concern of ranchers, rangeland scientists, and an increasingly-informed and concerned public. A currently accepted method for evaluating an ecosystem's state and sustainability is to understand the dynamics of soil C and N, and in particular, whether organic C is in a stable state or one of flux. Yet the mechanisms underlying C and N cycling in rangelands are not understood sufficiently to formulate management recommendations.

APPROACH: A mechanistic understanding of how grazing practices affect rangeland C fluxes will enhance our understanding of the system, and facilitate sustainable management solutions. Two approaches are being used to study C fluxes. One involves using a closed-chamber gas exchange system to characterize CO_2 exchange rates (CER) in m^2 plots along transects in heavily-, lightly- and non-grazed pastures at both the Central Plains Experimental Range (CPER, short-grass steppe), Nunn, CO, and at the High Plains Grasslands Research Station (HPGRS, mixed-grass prairie), Cheyenne, WY. Because the chamber measurements are limited in terms of their ability to track seasonal aspects of CER, bowen ratio/energy balance (BR) systems were also installed in a 35-acre exclosure at CPER and in a lightly-grazed pasture at HPGRS for continuous monitoring of CER.

RESULTS: After two years of measurements, a few patterns have emerged. At CPER, it appears that CER of exclosure plots are greater in May and June. These early season differences in CER appear to be due to a greater proportion of cool-season, C_3 species in the exclosure plots. This trend is not evident at HPGRS, where early-season CER is actually greater under grazing. The balance of C_3/C_4 species was not affected by grazing treatment at HPGRS, but leaf area index (LAI) was, with grazed plots having a higher LAI in the spring, which we believe accounted for their higher CER. These results suggest that the affects of grazing on C cycling and sequestration cannot be easily extrapolated from one grassland type to another, but will depend on how species of the particular plant community of a grassland interact and compete in response to grazing. This was our first year for the BR measurements, and unfortunately was not an overly-productive one due to intermittent equipment failure and a direct lightning strike. BR data that were collected look useful, and are particularly interesting in that they will allow us to observe immediate changes in system characteristics at the time of an important environment event, such as a rain storm.

FUTURE PLANS: The closed-chamber measurements will be conducted at least one more year. Cellular phones were bought, as well as a complete new BR system to replace the one destroyed by lightning, so the BR systems will be accessible by phone to better facilitate monitoring and timely calibration of equipment. Funding from ARS Global Change Grant will allow an expansion of this work to involve Gordon Hutchinson, Howard Skinner, and Jon Hanson to investigate below-ground soil and plant mechanisms involved in responses of rangelands to grazing and CO_2 enrichment.

HYDROLOGIC CHARACTERISTICS OF NATIVE SHORTGRASS PRAIRIE

G.W. Frasier, M. Weltz[1], L. Weltz[2], L. Ahuja[3] and K. Close[4]

PROBLEM: Runoff and infiltration processes on native semiarid rangelands do not follow classical theory. Spatial and temporal variable of infiltration are very difficult to evaluate and characterize.

APPROACH: Dye tracers were used to define and characterize water flow paths into the soil when using tension infiltrometers to measure infiltration rates. This data, combined with new techniques separating rainfall simulator runoff hydrographs into segments representative of different portions of the flow event is used to better characterize spatial and temporal variability of infiltration processes..

RESULTS: Dye tracers used in conjunction with tension infiltrometers on prepared soil columns show that the methodology used in operating the equipment must be carefully followed. It is virtually impossible to determine from the recorded data if the measurements represent the true infiltration values or if the equipment has been improperly placed in contact with the soil surface. The presence of layers or soil lens with lower permeability than the average soil mass tend to be the limiting or controlling factor during the initial stages of infiltration. Analysis of the initial segments of the runoff hydrograph indicate the presence of a soil surface layer that increases in infiltration with time. This characteristic could be a result of a partial water repellency of the soil surface. These infiltration features, soil lens and water repellency, are not apparent when measurements are only taken during equilibrium infiltration.

INTERPRETATION: Predicting infiltration and runoff from undisturbed rangeland areas can be improved with a better understanding of the actual process. Most current models of infiltration have serious limitations in properly characterizing the parameters to represent the undisturbed field conditions. In many natural rainfall events the storm duration is too short to produce equilibrium infiltration and runoff. Models based on disturbed soil profiles, ie. plowed fields, can not predict infiltration and runoff from undisturbed rangeland sites.

FUTURE PLANS: Studies will be continued to further define critical site parameters for characterizing infiltration on undisturbed rangelands using tension infiltrometers and dye tracers.

---

[1] USDA-ARS, Southwest Watershed Research Center, Tucson, AZ
[2] Consultant, Tucson, AZ
[3] USDA-ARS, Great Plains Systems Research Unit, Ft. Collins, CO.
[4] Department of Chemical and Bioresource Engineering, Colorado State Univ., Ft. Collins, CO

HYDROLOGIC CHARACTERISTICS OF A MONTANE RIPARIAN ZONE

G.W. Frasier, M. J. Trlica[1], W. Leininger[2], R. Pearce[3] and A. Fernald[4]

PROBLEM: Riparian ecosystems are the final terrestrial zone before runoff water enters a stream. The ability of these areas to remove sediments from overland water flow from uplands and roads is critical in reducing non-point source pollution of streams. The key element in evaluating sediment transport is quantifying the quantity of runoff water.

APPROACH: A rotating boom rainfall simulator was used to evaluate the effects of 3 vegetation height treatments in 2 montane riparian plant communities (grass and sedge) on runoff with a dry and a wet soil moisture condition.

RESULTS: There were no differences in time to runoff initiation that could be attributed to vegetation height treatment for either plant community. It usually required longer for runoff initiation in the sedge community compared to the grass community. Equilibrium runoff was lower in the sedge community compared to the grass community during the dry run. There were no differences in the wet run. Several runoff parameters had characteristics of runoff from water repellent soils. The organic layer on the soil surface exhibited signs of water repellency which reduced water infiltration during the initial stages of the rainfall simulation event.

INTERPRETATION: These results indicate that runoff and infiltration processes in the surface organic horizon of the riparian zones may not respond in the classical manner. This characteristic has important implications if criteria developed in areas with less organic matter on the soil surface is used to manage or predict overland flow water in the riparian stream bank zone.

FUTURE PLANS: Studies will be conducted to evaluate the impact of trampling by livestock on the runoff and sediment trapping characteristics of the riparian zone.

---

[1] Department of Rangeland Ecosystem Management, Colorado State Univ, Ft. Collins, CO
[2] Department of Rangeland Ecosystem Management, Colorado State Univ, Ft. Collins, CO
[3] Owens Valley Mosquito Abatement Program, Bishop, CA
[4] Department of Earth Resources, Colorado State Univ., Ft. Collins, CO

HYDROLOGIC CHARACTERISTICS OF A NATIVE SHORTGRASS PRAIRIE TREATED WITH ANIMAL, MUNICIPAL AND INDUSTRIAL BY-PRODUCTS

G.W. Frasier, G.E. Schuman, J.D. Reeder and R.H. Hart

PROBLEM: Disposing of various animal, municipal and industrial by-products is becoming a national concern. Disposal on rangelands is a promising alternative assuming there is no adverse effect on water quality or supply.

APPROACH: A rotating boom rainfall simulator was used to evaluate the effects of applying animal manures (fresh and composted), dried sewage sludge and phosphogypsum on runoff and infiltration characteristics at 2 native rangeland sites (shortgrass and mixed grass).

RESULTS: The treatments decreased runoff approximately 50% at the mixed grass site within 3 months after application but similar changes were not measured at the shortgrass site until 2 years later. There were indications a soil water repellency or crusting caused a temporary increase in the rate of runoff during the initial stages of the simulated precipitation events. This conditions was also observed on the control plots and may be a natural phenomena of rangeland soils with decomposing litter on the soil surface.

INTERPRETATION: These results indicate that a one time application of the wastes will probably not degrade the land and will improve infiltration characteristics.

FUTURE PLANS: Water quality data results will be analyzed to determine the quality of the runoff water from the treated areas.

UTILIZATION OF ANIMAL, MUNICIPAL, AND INDUSTRIAL WASTES ON SEMIARID RANGELANDS HYDROLOGY, SOILS AND VEGETATION

G.E. Schuman, J.D. Reeder, G.W. Frasier and R.H. Hart

PROBLEM: Rangelands are being considered as potential sites for utilization of municipal, industrial and animal wastes. However, little information is available concerning the application of waste materials to rangelands where incorporation into the soil is not feasible, and where the applications of waste products to rangelands may increase the quantity and quality of forage, and may improve water conservation. However, nutrients and heavy metals associated with the applied waste products have the potential to degrade surface and subsurface water quality, result in toxic levels of heavy metals in plant tissues, or cause undesirable shifts in plant species composition.

APPROACH: This study is being conducted at the Central Plains Experimental Range (CPER) near Nunn, CO, on short-grass prairie, and at the High Plains Grasslands Research Station (HPGRS) near Cheyenne, WY, on mixed-grass prairie. Treatments consisted of surface applications (23 metric tons/ha) in May, 1993, of (1) fresh feedlot cattle wastes, (2) composted feedlot cattle waste, (3) phosphogypsum, (4) dried sewage sludge, and (5) control (no treatment). The soil profile and peak vegetation production have been sampled annually. Runoff water quality and quantity were evaluated with a rotating boom rainfall simulator in May and August, 1993 (see separate report).

RESULTS: Response of vegetation to applied wastes has been limited in general to the sewage sludge and composted feedlot cattle waste treatments, which both supplied high levels of N(>450 kg N/ha) and P (>250 kg P/ha). Yearly variations in precipitation patterns and amounts have controlled the response of warm- and cool-season grasses to this added N and P. In 1993, warm-season grass production increased by 38-50% (to 960-1040 kg/ha) with application of these two waste materials, while drought conditions throughout the 1994 growing season limited plant response to residual N and P from the waste amendments. In 1995, cool season grass production increased by 230-425% (to 400-750 kg/ha), and annual forb production increased by 400-490% (850-1000 kg/ha) in response to residual nutrients from the composted manure and sewage sludge. In all three years, the composted manure and sewage sludge treatments increased annual forb production by at least 400%. Soil and plant samples collected in 1996 are currently being analyzed. Long-term sampling is required to determine the persistence of desirable increases in forage quality and quantity, and annual forb production accounted for <3% in all treatments in 1996. The sewage sludge, composted manure and phosphogypsum and nitrogen treatment continue to exhibit greater total production than all other treatments.

FUTURE PLANS: Vegetation and soil will be sampled for a minimum of two more years in order to assess changes in soil properties, nutrient/heavy metal leaching, forage production and quality, and plant community composition as a result of a one-time application of these waste products. Further summarization of the data will determine if a second waste application is applied and/or whether we expand this research to pasture size treatments using selected wastes.

CARBON AND NITROGEN DYNAMICS OF MARGINAL CROPLANDS RESEEDED TO GRASS COMMUNITIES

G.E. Schuman, J.D. Reeder, R.A. Bowman[1] and E.M. Taylor, Jr.

PROBLEM: A better understanding of the factors controlling soil organic matter formation and its activity is necessary to protect and restore the soil quality of marginal, highly erodible cropland. Alternative management of these lands to enable regeneration and provide economic benefit must be evaluated.

APPROACH: Field sites were established in 1987 at Egbert, Keeline and Arvada, Wyoming. Treatments included: (1) continued wheat-fallow cropping of marginal land, (2) plowed native grassland cropped to wheat-fallow, (3) grass established on long-term wheat-fallow marginal cropland, and (4) native grassland. Soil samples were collected annually from all treatments to assess soil C and N changes. Grass production data was collected from the native and seeded treatments. Wheat and straw production were also determined in the wheat cycle. This experimental design enabled calculation of C and N dynamics within the soil/plant system.

RESULTS: Soil and vegetation sampling was completed in 1995. After 60+ years of cultivation, total soil organic C and N had decreased by 25%, but the labile pool of soil organic matter had decreased by 55%. Four years after plowing native rangeland and cropping to wheat-fallow, total and labile C and N contents of the A horizon had decreased to the levels found in the crop lands that have been in production for 60+ years, mixing of A and B horizons by plowing in 1987 accounted for about 65% of this decrease in C and N. Loss of labile soil organic matter at the onset of cultivation was considerably more rapid than loss of total organic matter. Four years of established grass on marginal croplands increased C and N concentrations in the surface 2.5-7.5 cm of the soil profile; increases were more rapid in the sandy loam soils compared to the clay loam soil. Recovery of labile soil organic matter with the establishment of grasses on marginal cropland has been considerably more rapid than recovery of total organic matter. To simulate the contribution of a legume in the reestablished grass community, annual applications of N (34 kg N/ha) were made on half of each reseeded grass treatment plot. This additional N has restored N dynamics on this treatment to levels comparable to native rangeland. The study has been discontinued at two sites, Keeline and Arvada, and the land returned to the owners. Study treatments are being maintained at the Egbert site, but annual soil and grass production sampling has been discontinued. In 1996, wheat and straw production were determined at the Egbert site, and the first of a series of papers reporting the results of this study was submitted for publication.

FUTURE PLANS: Soil aggregate size distribution and the long-term C and N data will be summarized and manuscripts prepared.

[1] USDA-ARS, Central Great Plains Research Station, Akron, CO

CARBON AND NITROGEN BALANCE IN GRAZED SEMI-ARID RANGELANDS

G.E. Schuman, J.D. Reeder, J.A. Morgan and R.H. Hart

PROBLEM: Rangeland grazing management strategies affect forage production, plant community structure, soil chemical and physical properties, and the distribution and cycling of carbon (C) and nitrogen (N) within the plant/soil system. A better understanding of how grazing management affects rangeland C and N dynamics should improve our understanding of the system and help develop management technologies that ensure sustainability of our rangelands.

APPROACH: This study is being conducted at the High Plains Grasslands Research Station (HPGRS) near Cheyenne, WY, on mixed grass rangeland, and at the Central Plains Experimental Range (CPER) near Nunn, CO, on short grass rangeland. At the HPGRS, pastures grazed for 11 years at a heavy stocking rate under three management strategies (continuous, rotationally deferred, and short-duration rotation grazing) were compared to a continuous light stocking rate and to a livestock enclosure. At the CPER, pastures continuously grazed for the past 50 years at a heavy stocking rate were compared to a continuous light stocking rate and to a livestock exclosure. At both locations, the soil profile (0-60 cm), and vegetation (roots, aboveground litter, standing dead and live biomass) were evaluated for C and N to determine the influence of these management strategies and stocking rates on C and N cycling and distribution in the plant/soil system.

RESULTS: After 11 years of imposed grazing treatments on the mixed grass range at the HPGRS, the total amounts of C and N (kg/ha) in the plant/soil system were not significantly different among the grazing treatments. However, the distribution of C and N within the plant/soil system differed among treatments; these differences were due to stocking rate rather than grazing management strategy. The amount of C and N in the surface 15 cm of the soil profile of non-grazed exclosures was significantly lower than in all grazed treatments. Aboveground vegetation contained greater quantities of C and N in the non-grazed exclosures than in the grazed pastures, while quantities of C and N in roots were not significantly different between grazed and ungrazed treatments. The data suggest that grazing may have enhanced surface soil quality by redistributing C and N to the surface 15 cm of the soil profile. Soil and plant samples collected from the short grass range at the CPER are being analyzed.

FUTURE PLANS: The HPGRS phase of this study has been completed and a manuscript reporting the C and N balance of the system is in review. Data collected from the CPER are being summarized and will be compared with canopy $C0_2$ exchange rates (see other report). Global Change funding will enable us to further evaluate the effects of grazing on soil C and N changes. A study utilizing ^{15}N and ^{13}C will be initiated, with Gordon Hutchinson[1], to assess the rate of formation of soil organic matter and the below ground partitioning of C and N.

---

[1] USDA-ARS, Soil, Plant, Nutrient Research Unit, Ft. Collins, CO

ROLE OF VESICULAR-ARBUSCULAR MYCORRHIZAE ON DROUGHT STRESS TOLERANCE OF BIG SAGEBRUSH

G.E. Schuman, P.D. Stahl[1] and S.E. Williams[1]

PROBLEM: The importance of Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis) in stabilizing the landscape and enhancing wildlife habitat is well documented. Although big sagebrush is one of the most common and widespread shrubs in the Western U.S., reestablishment of this species on disturbed rangelands by direct seeding has proven difficult. Several theories exist to explain this difficulty in establishment; they range from poor seed quality and seed dormancy, to a lack of adequate levels of mycorrhizal inoculum in the disturbed soil.

APPROACH: A greenhouse study was conducted to test two hypotheses: (1) mycorrhizal sagebrush seedlings are more tolerant to soil moisture stress than non-mycorrhizal sagebrush seedlings, and, (2) is there an interaction between seedling age and mycorrhizal status on soil moisture stress tolerance. Undisturbed grassland soil was collected to accomplish this greenhouse study. A portion of the soil was autoclaved to eliminate the mycorrhizal fungi from the soil. A water extract of non-autoclaved soil (filtered through a 24um filter to remove mycorrhizal fungi) was applied to the autoclaved soil to restore other indigenous soil microorganisms other than the arbuscular mycorrhizal fungi. This autoclaved and fresh, untreated soil were used in a pot culture. Sagebrush was seeded into 108, 15 cm pots of each of the two soil treatments. Two seedlings were maintained in each pot to assess moisture stress tolerance differences. Moisture stress tolerance was done on 30, 45, 60, 90, 120 and 150 day old sagebrush seedlings. Water was withdrawn from a subsample of pots from each of the two soil treatments and days until mortality recorded. Immediately upon death the seedlings were removed from the soil and the roots evaluated for mycorrhizal infection and soil moisture determined.

RESULTS: Sagebrush seedlings in the untreated soil developed arbuscular mycorrhizae on 65-86% of the root segments examined; however, seedlings from the non-mycorrhizal soil only exhibited infection of 1-2% of the root segments examined. At all seedling ages the degree of soil dryness resulting in death of the mycorrhizal seedlings was significantly lower than for the non-mycorrhizal seedlings. For example, the 45 day old mycorrhizal seedlings were able to tolerate an average of -3.22 MPa of moisture stress compared to the non-mycorrhizal which were only able to tolerate an average of -2.77 MPa of moisture stress before mortality. The data also showed that as seedlings became older the influence on moisture stress tolerance was greater for the mycorrhizal seedlings compared to the non-mycorrhizal. These findings stress the importance of good topsoil management to ensure adequate mycorrhizal inoculum is present during the early seedling development.

FUTURE PLANS: This research has been completed and a manuscript reporting the results of the study is in the review process.

[1] Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY

GRASS: GRAZING RATES AND STRATEGIES STUDY

R.H. Hart, G. E. Schuman, G.W. Frasier, J.W. Waggoner, Jr.[1], and M.A. Smith[1]

PROBLEM: Claims for the benefits of short-duration or time-controlled rotation grazing systems have received a great deal of publicity and some official recognition by NRCS and other agencies. A study was begun in 1982 to evaluate the responses of cattle, vegetation, soils, and hydrology to three grazing strategies at three stocking rates.

APPROACH: Crossbred and Hereford steers initially weighing 302 kg grazed native range 6 June-26 September 1996. Strategies included continuous or season-long grazing © and time-controlled rotation grazing in 8 (S8) and 24 (S24) paddocks. Stocking rates in 1996 were 20.5 (light), 46.7 (moderate) and 62.2 (heavy) steer-days ha^{-1}. Steers were weighed every 28 days. Peak standing crop (PSC) was estimated inside 4 exclosures per pasture 2 and 8 August.

FINDINGS: Peak standing crop was 1170 kg ha^{-1}, with no differences among strategies or stocking rates. Average daily gains were CL, 1.29; CM, 1.37; CH, 1.32; S8M, 1.14; S8H, 1.03; and S24H, 1.13 kg. Gains under time-controlled rotation grazing were significantly less than gains under season-long grazing.

FUTURE PLANS: Manuscript covering the first 13 years of this study has been accepted by the *Journal of Range Management* and will be published in November 1997. This study will be continued at least through 2000.

[1] Dept. of Rangeland Ecology and Watershed Management, University of Wyoming

LONG-TERM GRAZING INTENSITY STUDY, CENTRAL PLAINS EXPERIMENTAL RANGE

R.H. Hart and M. Ashby

PROBLEM: Studies of the impact of grazing intensity on steer gains and range vegetation seldom last more than a few years. Data is needed on effects over several decades.

APPROACH: In 1939, a replicated study of 3 grazing intensities was begun at the Central Plains Experimental Range. Over the years replications were dropped until by 1960 a single pasture of each of 3 intensities remained. In 1996, yearling heifers grazed the study 14 May-31 October at light, moderate or heavy stocking rates of 15, 20 or 25 heifers per 129.6 ha (320 acres) or 19.7, 26.2 or 32.8 heifer-days ha^{-1}. Heifers were weighed every 4 weeks. Peak standing crop was estimated from exclosures distributed over the entire area of each pasture. A manuscript comparing 1992-1994 plant community compositions to earlier estimates, and relating heifer gains to grazing pressure over the life of the study, is in peer review. Major findings include 1) moderate grazing has little effect on plant communities; 2) heavy grazing increases blue grama and nearly removes cool-season grasses; and 3) light or zero grazing increases cool-season grasses, pricklypear and fringed sagewort.

FINDINGS: Average daily gains of heifers were 0.58, light; 0.56, moderate; and 0.54 kg, heavy. Peak standing crops were 861, light; 802, moderate; and 656 kg ha^{-1}, heavy.

FUTURE PLANS: This study will be continued indefinitely. A manuscript describing the effects on plant communities of thinning shortgrass stands with glyphosate is in peer review.

GRASS CPER: GRAZING STRATEGIES ON SHORTGRASS AT CPER

R.H. Hart

PROBLEM: Large-pasture studies of the impact of grazing strategies on shortgrass prairie are needed.

APPROACH: Time-controlled rotation grazing was implemented on a 7-paddock layout, each paddock containing 65 ha (160 acres). One paddock was sub-divided into 3 equal sized sub-paddocks; these mimic a portion of a 21-paddock layout. An undivided 259-ha (640 acres) pasture was grazed season-long. Three-pasture rotationally deferred grazing was implemented on three 152-ha (373 acre) pastures, with grazing on one pasture deferred until July. Stocking rate was 22.0 steer-days ha^{-1}, from 13 May to 10 October. Steers were weighed on and off pasture.

FINDINGS: Average daily gains of steers were 0.86, season-long; 0.90, time-controlled rotation; and 1.00 kg, rotationally deferred grazing.

FUTURE PLANS: This study will be continued for at least 12 years.

GRIPES: GRAZING RANGE AND IMPROVED PASTURE EXPERIMENT ON SHORTGRASS

R.H. Hart

PROBLEM: Costs of cattle production could be reduced if the grazing season could be extended by grazing complementary pastures in spring and/or fall, before and after the grazing season on shortgrass rangeland.

APPROACH: Two pastures of 16 ha each, containing dense uniform stands of fourwing saltbush were grazed 1 March-9 May at stocking rates of 21.9 (light) and 35.0 (moderate) heifer- days ha^{-1}. They will be grazed at similar stocking rates October-December. 'Hycrest' wheatgrass and 'Bozoisky' wildrye were grazed at 25.0 and 21.9 heifer-days ha^{-1} in spring and fall, respectively (S&FL) or at 33.3 and 29.2 heifer-days ha^{-1} (S&FM). Hycrest was grazed at 50.0 (SL) or 66.7 (SM) days ha^{-1} in spring only, and Bozoisky was grazed at 43.8 (FL) and 58.3 (FM) days ha^{-1} in fall only. Spring grazing was 15 Apr-4 June and fall grazing 31 October-5 December. After spring grazing, heifers were moved onto native rangeland. Plant community compositions of these pastures, and of rangeland pastures grazed beginning in May, were estimated as baseline data for a comparison of the effect of delayed spring grazing.

FINDINGS: Spring average daily gains on saltbush were light, 0.70 and moderate, 0.44 kg; fall gains have not yet been analyzed.

Total gains ha^{-1} (kg) on complementary grass pastures were:

	SL	SM	FL	FM	S&FL	S&FM
Hycrest wheatgrass	45.3	53.9	---	---	36.7	59.4
Bozoisky wildrye	---	---	22.8	26.2	41.9	53.8

Hycrest in spring produced higher gains than Bozoisky in fall, but when both were grazed spring and fall there was little difference. Production of Hycrest and Bozoisky in spring was estimated at 2100 and 1420 kg ha^{-1}.

FUTURE PLANS: This study will continue for 6 years.

NASTY: NUTRIENT ACCUMULATION NEAR STOCKWATER--TEST OF YIELD

R.H. Hart

PROBLEM: Increased forage production and shifts in botanical composition of vegetation near stockwater tanks suggested accumulation of nitrogen as a result of increased cattle defecation and urination near water.

APPROACH: On the GRASS experiment and on the HR Land Co. East of Cheyenne in 1993 and 1994, two exclosures were placed at 10 or 12.5 m and at 20 or 25 m from stockwater tanks serving 1 or 2 pastures grazed season-long, 4 or 8 paddocks in an 8-paddock rotation layout, or 16 paddocks in a 43-paddock rotation layout arranged radially around the tank. Exclosures were also placed at 50 m from the tank serving 16 paddocks and at >100 m from all tanks. Herbage from two quadrats in each exclosure was clipped, divided into major species and species groups, dried, and weighed.

FINDINGS: Total herbage production was greater near water in both years; production of western wheatgrass was greater near water in a year with above-average spring precipitation (1993) and production of blue grama was greater near water in a year with above-average summer precipitation (1994). Paddock numbers had no consistent effect on production or composition. When data were analyzed by stocking density rather than paddock number, the increases in production near water were greater at higher stocking densities. A manuscript is in peer review.

FUTURE PLANS: This study has been completed.

MODELING PLANT AND ANIMAL RESPONSES ON RANGE

R.H. Hart and C.E. Ring[1]

PROBLEM: Models are needed which are simple enough to run on desk-top computers with inputs readily available to the livestock producer, but complete enough to aid decision-making in livestock management.

APPROACH: At an ARS-NRCS conference in Dallas, TX, interest was expressed in linking the NRCS Grazing Lands Application (GLA) package to the ARS STEERISK model. GLA is useful for summarizing vegetation information but lacks a useful stocking rate guide, while STEERISK would benefit from the inclusion of GLA information on forage production and preference.

FINDINGS: In cooperation with the NRCS Grazinglands Resources Technical Team at Cheyenne, stocking rate predictions of GLA and STEERISK are being compared with one another and with actual field data.

FUTURE PLANS: If GLA and STEERISK linkage are successful, journal and popular articles will be prepared and the programs will be distributed to producers, range technicians, and other interested parties.

SUSTAINABLE RANGELAND-BASED BEEF CATTLE PRODUCTION SYSTEMS (SARE GRANT)

R.H. Hart, J.W. Waggoner, Jr.[1] and M.A. Smith[1]

PROBLEM: Changing calving and weaning dates to match nutrient requirements of a cow-calf herd more closely to the availability of green forage has been suggested as a way of reducing production costs and increasing sustainability of a cow-calf operation.

APPROACH: Sixty-eight Hereford cows calved 24 Feb-31 Mar (March calving) or 29 Apr-28 May (May calving). Cow-calf pairs were stocked on native range 4 June-17 December at 4.4 or 5.3 ha per pair. Calves were weaned at approximately 165 or 192 days old.

FINDINGS: March calves weighed 188 and 214 kg, respectively, when weaned at 169 and 196 days; calves born in May weighed 177 and 180 kg when weaned at 162 and 190 days. Cows calving in March gained 0.51 kg day^{-1} June-December; cows calving in May gained 0.24 kg. Stocking rates had no effect on cow gains or calf weaning weights. Age at weaning had no effect on cow gains. The availability of green feed soon after calving did not improve spring gains enough to compensate for weight losses produced by nursing calves in late fall when forage availability and quality were low. Bull and heifer calves weighed 195 and 184 kg, respectively, at weaning; cows with bull and heifer calves gained 0.35 and 0.41 kg day^{-1}.

FUTURE PLANS: This study will continue for 2 more years. It may be re-designed and continued longer after analysis of the first 3 years of data.

[1] Dept. of Rangeland Ecosystems and Watershed Management, Univ. of Wyoming

RANGELAND RESOURCES RESEARCH UNIT

Publications

Augustrina, R., D.T. Booth and R.H. Abernethy. 1996. Evidence of cell deterioration in winterfat seed during refrigerated storage. p. 4. In: Proc. 49th Ann Mtng., Soc. for Range Manage. Abstract.

Bai, Y., D.T. Booth and E.E. Roos. 1996. Influences of initial seed moisture and humidification on seed germination of Wyoming big sagebrush. In: N.E. West (ed.) Proc. of the 5th International Rangeland Congress. p. 27. Salt Lake City, Utah. 23-28 July. Society for Range Management, 1839 York St., Denver, CO. 80206.

Booth, D.T., Y. Bai and E.E. Roos. 1996. Wyoming big sagebrush seed quality related to debearder operation during seed cleaning and storage. In: N.E. West (ed.) Proc. of the 5th International Rangeland Congress. p. 60. Salt Lake City, Utah. 23-28 July. Society for Range Management, 1839 York St., Denver, CO. 80206.

Chen, D.-X., H.W. Hunt and J.A. Morgan. 1996. Responses of a C_3 and C_4 perennial grass to CO_2 enrichment and climate change: Comparison between model predictions and experimental data. Ecological Modeling 87:11-27.

Drinkwater, L.E., C.A. Cambardella, J.D. Reeder and C.W. Rice. 1996. Potentially mineralizable nitrogen as an indicator of active soil N. In: Handbook of methods for assessment of soil qual. Am. Soc. Agron.

Frasier, G.E., R.H. Hart and G.E. Schuman. 1996. Impact of grazing intensity on infiltration/runoff characteristics of a shortgrass prairie. p. 159-160. In: Proc. 5th Intl. Range Congress.

Frasier, G.W., G.E. Schuman, J.D. Reeder, P. Lyman and D. Mueller. 1996. Hydrologic impact of animal, municipal and industrial waste on rangelands. Third Ann. Symp. Central Plains Exper. Range. January 11, 1996, Ft. Collins, CO (Abstract).

Frasier, G.W. 1996. Small watershed studies: Infiltration data and research needs. P. 57-64. In: Proc., Real World Infiltration Workshop, USDA, ARS, Pingree Park, CO. Colorado Water Resources Research Institute Information Series, No. 86, Colorado State University, Fort Collins, CO.

Hart, R. H. and W. A. Laycock. 1996. Repeat photography on range and forest lands in the western United States. J. Range Manage. 49:60-67.

Hart, R. H., M. J. Samuel, W. A. Orso, M. A. Smith and J. T. Manley. 1996. Cattle and vegetation responses to grazing pressures and strategies on mixed-grass prairie. pp. 213-214. In: Neil E. West (ed.) Rangelands in a Sustainable Biosphere. Proc. 5th Intl. Rangel. Cong., vol. I.

Hart, R. H., W. D. Willms and M. R. George. 1996. Cool-season grasses in rangeland. p. 357-381. In: L. E. Moser, D. R. Buxton and M. D. Casler (eds.) Cool-Season Forage Grasses. Amer. Soc. Agronomy, Madison, WI.

Hart, R. H. 1996. Can we broaden the rangeland audience without denying our grazing heritage? Rangelands 18:173-177.

Hunt, H.W., Elliott, E.T., Detling, J.K., Morgan, J.A. and Chen, D.-X. 1996. Responses of a C_3 and C_4 perennial grass to elevated CO_2 and climate change. Global Change Biology. 2:35-47.

Hunt, H.W., J.A. Morgan and J.J. Read. 1996. Simulating growth and partitioning in prairie grasses grown under different CO_2 and water regimes. GCTE & COST 619 Workshop "Interactions Between Elevated CO_2 and Water in Grasslands," Davos, Switzerland. (Abstract)

Krall, J. M. and G.E. Schuman. 1996. Integrated dryland crop and livestock production systems on the Great Plains: Extent and Outlook. J. Production Agriculture 9:187-191.

LeCain, D.R., J.A. Morgan, G.E. Schuman, R.H. Hart and J.D. Reeder. 1996. Canopy $C0^2$ Exchange rate of grazed and ungrazed pastures at the CPER. Third Ann. Symp. Central Plains Experi. Range. January 11, 1996, Ft. Collins, CO (Abstract).

Read, J.J. and J.A. Morgan. 1996. Growth and partitioning in *Pascopyrum smithii* (C_3) and *Bouteloua gracilis* (C_4) as influenced by carbon dioxide and temperature. Ann. Bot. 77:487-496.

Reeder, J.D., G.E. Schuman, G.F. Frasier and R.H. Hart. 1996. Utilization of municipal, industrial and animal wastes on semiarid rangelands. Third Ann. Symp. Central Plains Experi. Range. January 11, 1996, Ft. Collins, CO (Abstract).

Schuman, G.E., J.A. Morgan, J.D. Reeder, D.R. LeCain, R.H. Hart and J.T. Manley. 1996. Response of soil carbon and nitrogen to grazing on a mixed-grass prairie in Wyoming, USA. p. 235-236, Vol. 2. In: Soil Science, Raising the Profile, Australian and New Zealand National Soils Conference, July 1-4, 1996. University of Melbourne, Melbourne, Vic., Australia.

Schuman, G.E. and R.E. Ries. 1996. Recent mined land reclamation advancements in the Great Plains, USA. p. 90-100. In: Proc. 3rd International and the 21st Annual Minerals Council of Australia Environmental Workshop, October 14-18, 1996. Newcastle, NSW. Minerals Council of Australia, Dickson, ACT. Australia.

Schuman, G.E. 1996. Rehabilitation of abandoned bentonite mined lands. p.O13. In: Proc., International Conference on the Remediation and Management of Degraded Lands, December 3-6, 1996, Hong Kong. Hong Kong Baptist University, Department of Biology, Kowloon Tong, Hong Kong.

Stahl, P.D., G.E. Schuman, S.E. Williams, and S.M. Frost. 1996. Influence of arbuscular mycorrhiza on water stress tolerance of big sagebrush seedlings. Agronomy Abstracts, p. 232.

SOIL-PLANT-NUTRIENT RESEARCH UNIT

Ronald F. Follett, Research Leader
Federal Building
301 S. Howes, Room 407
Fort Collins, CO 80522
TEL: (970) 490-8200
FAX: (970) 490-8213

INTERNET: rfollett@lamar.colostate.edu

TABLE OF CONTENTS

CRIS PROJECTS:

5402-11000-005-00D Land Use, Land Management and Climate Change: Interactions of C/N Cycles, Trace Gas Fluxes and Soil Quality in Agroecosystems
5402-11000-005-01T Shortgrass Steppe Ecosystem Dynamics and Trace Gas Exchange Under Elevated CO_2
5402-11000-005-07S Building a U.S. Trace Gas Network
5402-11000-005-08S Shortgrass Steppe Ecosystem Dynamics and Trace Gas Exchange Under Elevated CO_2
5402-12130-003-00D Improve Nitrogen Use Efficiency and Water and Environmental Quality
5402-12130-003-05S U.S. Agroecozones Using GIS - Colorado
5402-12130-003-06S U.S. Agroecozones Using GIS - Texas
5402-12130-003-07G Soil and Water Conservation
8001-12120-007-01P Use of Improved Tillage Systems to Increase Soil Organic Carbon and N Use Efficiency in Vertisols in Mexico

MISSION STATEMENT

To develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize farm profitability, maintain environmental quality and sustain long-term productivity.

TECHNOLOGY TRANSFER

Soil-Plant-Nutrient Research Unit

J.A. Delgado

1. Dr. Delgado was invited to the 13th Annual Potato/Grain conference to present a paper about Preliminary assessment of N-uptake and NO_3-N accumulation of winter cover crops and their effect on soil and water quality in the San Luis Valley of Colorado. 13th Annual Potato/Grain conference. (Monte Vista, Colorado, February 13 - 15).

2. Dr. Delgado and Dr. Follett presented the result of a potential sap test to determine nitrate nitrogen concentrations in aboveground biomass of winter cover crops at the 1996 Annual ASA Meetings in Indianapolis, Indiana.

3. Dr. Delgado met with San Luis Valley NRCS Area Office personnel to discuss assessment of N-uptake patterns of winter cover crops in the San Luis Valley. This transfer of information of winter cover crop growth and N uptake patterns increases the knowledge about N cycling in these systems.

4. Dr. Delgado and Dr. Mosier discussed the potential to use slow release fertilizer to control NO_3-N leaching with Dr. Sadao Shoji, Professor Emeritus of Tohuku University. Dr. Shoji visited the SPN unit in Fort Collins. Drs. Shoji, Mosier, and Delgado visited with NRCS personnel and farmers of the San Luis Valley of south central Colorado.

5. Dr. Delgado, Dr. Follett, Mr. Sharkoff, and Ms. Brodahl published the NITROGEN MANAGEMENT NLEAP FACTS Sheet, Nitrogen content and indices of selected crops grown in the San Luis Valley of south central Colorado and their use in simulating crop N uptake and soil N transformations. Reprints were requested by NRCS personnel.

6. Dr. Delgado, Ms. Brodahl, Dr. Shaffer, Dr. Follett, and Mr. Sharkoff published the NITROGEN MANAGEMENT NLEAP FACTS Sheet, A list of definitions to consider when using the NLEAP model to evaluate N management practices in soils containing coarse fragments. Reprints were requested by NRCS personnel.

7. Dr. Delgado and Ms. Brodahl using data collected from the San Luis Valley studies and preliminary results of NLEAP computer outputs, have incorporated modifications into a test version of the NLEAP sequential model to improve predicted simulations of residual soil NO_3-N.

8. Dr. Delgado was accepted for Faculty Affiliate status in the Department of Soil and Crop Sciences at Colorado State University.

9. Dr. Delgado trained and supervised Mr. David Wright, undergraduate student from the Soil and Crop Sciences Department at CSU in the use of the NLEAP computer model. Mr. Wright used NLEAP to simulate the effect of cropping systems in residual soil NO_3-N available to leach. These simulations were used to present an undergraduate student report to fulfill Mr. Wright's requirements for his independent study, AG 495.

R.F. Follett

10. Dr. Follett taught the section on Soil Fertility to NRCS, industry, and other individuals from CO to assist them in preparing to take their Certified Crop Advisor (CCA) examinations. The CCA program is sponsored by the American Society of Agronomy.

11. February 13, 1996 -- Invited to the Colegio de Postgraduados in Texcoco, Mexico to present a seminar entitled, "Carbon Sequestration in Soils of the Historic Grasslands of the United States as it may relate to Global Climate Change".

12.. February 14, 1996 -- Invited to the Research Center of INIFAP in Torreon, Mexico to present a seminar entitled, "Overview of Nitrogen Management and Nitrate Leaching for Irrigated Crops" and to advise on possible causes and N-management alternatives for dairies near Torreon that have high levels of groundwater nitrate and observed infertility problems in their dairy cows.

13.. Dr. Follett, along with S. Wilkins, coordinated and consolidated the development of a 107 page report for the 1995 USDA-ARS CO-WY Research Council and distributed over 500 copies to ARS customers, cooperators, and scientists.

14. Dr. Follett continues to meet with and provide technology transfer inputs to the joint ARS/NRCS/CASCD research committee at about six-month intervals.

15. At the request of the Undersecretary of USDA/REE, Dr. Follett lead a multi-location effort and developed the report, entitled "Determination of Agroecozones in the continental United States. Evaluation study Report (funded on January 23, 1996 and completed report submitted on April 24, 1996 to Dr. Karl N. Stauber, USDA Under Secretary for Research, Education, and Economics). 168p". The report was authored by: R.F. Follett, J. Arnold, M. Brodahl, J. Cipra, P. Doraiswamy, T. Elliott, D.A. Farrell, I. Flitcroft, K. Killian, K. Paustian, R. Srinivasan, and S. Waltman.

16. In July, Dr. Follett, along with E.G. Pruessner and J. Roth, assisted the CO Chapter in hosting the annual international meetings of the Soil and Water Conservation Society at Keystone, CO. About 800 people attended from across the USA and from several foreign countries.

17. Dr. Follett, in cooperation with Dr. Rattan Lal (OH State Univ.) and Dr. John Kimble (NRCS), organized a conference in Columbus, OH entitled, "Carbon Sequestration in Soil". The Conference was attended by about 140 participants from 20 countries and will result in the publication of three books.

18. December 2-7, 1996 -- Invited to Celaya, Mexico, along with E.D. Buenger, as part of a project funded by USDA/FAS/ICD/RSED to advise and help establish an ^{15}N study for a nitrogen by tillage/residue management field-experiment.

19. In December, 1996, Dr. Follett was appointed by the Administrator of ARS to serve as the ARS Technical Advisor to the National Association of Conservation Districts (NACD) for the Great Plains.

W. J. Hunter

20. Dr. Hunter was invited to present a seminar titled "The use of vegetable oil to bioremediate water containing high levels of nitrate" to the Department of Chemical and Bioresource Engineering, Colorado State University, Fort Collins, CO. 1996.

21. Dr. Hunter supplied information on the use of vegetable oil to bioremediate high nitrate water to the news media and to individuals, companies and communities. These efforts have resulted in a number of popular press news articles. A partial listing follows: "Vegetable Cooking Oil Is Natural Carbon Filter" in Ground Water Monitoring and Remediation 16(3):10; "Oily microbes eat nitrates" in AG Innovation News 5(4):12 (10/96); "Vegetable Cooking Oil a Natural Carbon Filter" in Groundwater Monitoring and Remediation Summer 1996 issue page 10; "Inexpensive vegetable cooking oils might be used to clean groundwater contaminated with nitrogen fertilizer" in Quarterly Report, Jan.-Mar., 1996; articles were also published in USA Today 124(2613):6 (June 1996); and in NMPro Magazine, Summer, 1996.

22. Commercial sales by Urbana Laboratories of a legume bacterial inoculant developed by Drs. Hunter and Kuykendall (ARS Beltsville) continued in 1996. Sales begin in early 1995. Enough inoculum has been sold to treat over a half a million acres of soybean.

G.L. Hutchinson

23. Dr. Hutchinson serves on the Biogenic Emissions Committee for the Emission Inventory Improvement Program sponsored by the State and Territorial Air Pollution Program Administrators, Association of Local Air Pollution Controls Officials, and the U.S.E.P.A. Its purpose is to provide agencies with the necessary tools to prepare consistent, reliable emission inventories through the adoption of standardized procedures.

A.R. Mosier

24. Co-convener of International Workshop on NO_x Emission from Soils, Tsukuba, Japan, March 4-6, 1996. The purpose of the Workshop was to integrate existing field and laboratory studies on NO and N_2O emissions from soils in the world to evaluate the impact of soil NO_x emissions on regional and global atmospheric chemistry.

25. Co-convener of International Workshop on Comparison of Simple Trace Gas Models with Field and Laboratory Data, Fort Collins, Colorado, October 15-19, 1996. The purpose of the workshop was to integrate observed trace gas fluxes from a variety of ecosystems into simple trace gas flux models to facilitate the use of data in regional and global climate change studies.

26. Chair of steering committee for U.S. Trace Gas Network (TRAGNET). The role of TRAGNET is to develop a data set of soil-atmosphere exchange of trace gases from a variety of ecosystems that are to be used by modelers to help understand the role of terrestrial ecosystems in atmospheric chemistry and climate change.

27. Co-chair of the OECD/IPCC expert group on National Inventory Methodology for N_2O in Agriculture. This group provides the methodology for which countries calculate specific "greenhouse gas" emissions in accord with the Global Climate Change Convention.

28. Provided training in ^{15}N technology and trace gas analysis during a one week visit for Dr. Pornpimol Chaiwanakupt and a three-month visit for Dr. Sakorn Phongpan, from the Thailand Department of Agriculture. Both visits were funded by the International Atomic Energy Agency. The goal of continued research interactions is to improve fertilizer N use efficiency in rice-based cropping systems in Thailand.

29. Provided two months of training in trace gas measurement in grassland systems to Yanfen Wang from the Department of Plant Ecology, Institute of Botany, Chinese Academy of Sciences, Beijing, China. The goal of this interaction is to help facilitate a trace gas measurement program in northern China to assess the impact of agricultural and range systems on global atmospheric trace gas concentrations.

30. As part of an effort to extend information concerning impact of agriculture on the soil-atmosphere exchange of N trace gases and their effects on regional and the global atmospheric chemistry, edited a special issue of the journal Nutrient Cycling in Agroecosystems that concerns NO emissions from soils and its influence on atmospheric chemistry.

31. As a part of an effort to disseminate information concerning the impact of agriculture on the soil-atmosphere of "greenhouse" gases and their effect on global atmospheric concentrations of these gases, edited a special issue of the journal Nutrient Cycling in Agroecosystems entitled: Soil--Source and Sink of Greenhouse Gases.

EFFECT OF DIFFERENT CROPPING SEQUENCES ON SOIL QUALITY AND ITS RELATIONSHIP TO WATER QUALITY

J.A. Delgado and R.F. Follett - Co-investigator: R.T. Sparks[1]

PROBLEM: It has been reported that nitrogen management practices in the San Luis Valley (SLV) increase residual soil NO_3-N, thus increasing the potential NO_3-N available to leach (NAL). Crop rotations can be used to protect soil and water quality in the SLV. Crop management practices in the SLV, especially when winter cover rye (WCR) is incorporated into a potato:potato rotation, have the potential to increase the amount of crop residue that is returned into the surface soil (**Table 1**). There is potential to use computer models to simulate N cycling in the valley and its effect on soil and water quality. If computer models are to be used to determine the effects of crop rotations on soil quality and its relation to water quality, calibration and validation of crop residue and soil organic matter (SOM) mineralization is needed for the SLV.

APPROACH: We are studying the effect of crop rotations such as potato:potato:grain; grain:grain: potato; and potato:WCR:potato rotations on different compartments of N and C in the SOM.

RESULTS: Preliminary results show that WCR, reduced soil erosion, returned organic C and N to the surface soil and improved soil and water quality. The incorporation of grains into potato:potato rotations has the potential to improve soil and water quality. Data about the effects of crop rotations on compartmentalization of C and N in the SOM are currently being analyzed.

Table 1. Total N content in different crops grown in the San Luis Valley.

Crop	Plant parts	Time of sampling	N in crop residue (kg N/ha)	Plant C/N (ratio)
Barley	Stalks & chaff	Harvest	35 - 44	76 - 85
Potato	Vines & roots	Before vine kill	22 - 62	10 - 18
Spring Wheat	Stalks & chaff	Harvest	40 - 66	54 - 70
Winter Rye	Whole plants	Before spring kill	90 - 300	9 - 17

Future Plans: Additional studies will be conducted to study the potential to simulate the effects of crop rotations on soil quality and its relationship to water quality in the SLV.

[1]USDA-NRCS, Area Office, Alamosa, CO

CALIBRATION OF NLEAP FOR THE SAN LUIS VALLEY WATER QUALITY PROJECT

J.A. Delgado and R.F. Follett - Co-investigator: J.L. Sharkoff[1]

PROBLEM: In the San Luis Valley (SLV) of south central Colorado nitrate (NO_3-N) leaching has been identified as an event that can affect water quality. Recent studies found well water NO_3-N concentrations as high as 75 ppm, north of the town of Center in the SLV. The combination of use of N fertilizer, high water table and sandy soils are factors that contribute to this elevated concentration of NO_3-N in ground water.

APPROACH: USDA-ARS and USDA-NRCS have been using NLEAP (Nitrate Leaching and Economic Analysis Package), as a computer software package, capable of providing an assessment of farm management practices on NO_3-N leaching. ARS is evaluating the capability of NLEAP to simulate the transport of NO_3-N out of the root zone of different crops grown under different soil textures and N management practices in the SLV. Crop planting and harvesting dates, N and water management inputs and timing, soil and climate information, and expected yield have been collected for about 25 sites. As part of this validation/calibration process an NLEAP model index file which contains soil and plant parameters is being evaluated for the SLV. This index file will be calibrated with information collected in a series of these sites. For validation, this SLV index file will be then independently tested in other sets of randomly selected sites where information has been collected but not used in the calibration process.

RESULTS: Sensitivity analyses showed that improvement in model simulations can be achieved by developing a local region index data base file. Preliminary results for over 23 sites, show the potential for NLEAP to simulate the transport and movement of NO_3-N between the top 0.0 - 0.3 m and 0.3 to 1.5 m depths ($P<.001$).

The effectiveness of NLEAP to simulate residual soil NO_3-N available to leach and its transport ($P<.0.001$) will be tested by using sensitivity analyses, statistical analyses and other adequate tests. Preliminary simulations suggest that crop decomposition, soil organic mineralization and N uptake indexes need further evaluation.

Preliminary data from the calibration of NLEAP for these different crops and for agricultural practices in the San Luis valley have been published in two NITROGEN MANAGEMENT NLEAP FACT sheets. Final data describing the results from the calibration/validation processes will be published.

FUTURE PLANS: Replications at each site will be used to evaluate field spatial variability and model variability for computer simulated outputs. The validation/calibration effort will continue across different cropping systems, different soil textures and agricultural practices including, minimum tillage, organic amendments, center pivot irrigation, use of slow release fertilizers, and other practices conducted in the SLV.

---

[1] USDA-NRCS, San Luis Valley Water Quality Demonstration Project, Monte Vista, CO.

TEST OF THE NLEAP SEQUENTIAL MODEL TO ASSESS THE EFFECT OF WINTER RYE IN PROTECTING WATER QUALITY

J.A. Delgado and R.F. Follett - Co-investigators: M. K. Brodahl[1] and R.T. Sparks[2]

PROBLEM: In the San Luis Valley (SLV) of south central Colorado nitrate (NO_3-N) leaching is identified as affecting water quality. There is a potential to use winter cover rye (WCR) as a mitigation alternative to scavenge soil N and reduce NO_3-N available to leach (NAL).

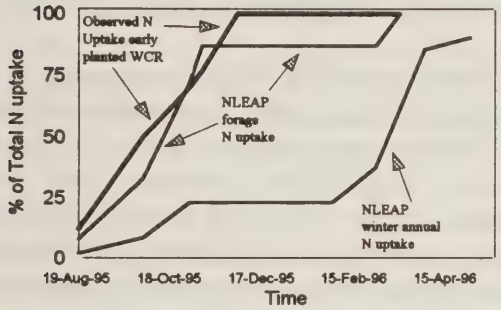


Figure 1. *Observed N uptake for early planted WCR and NLEAP simulated N uptake for WCR as winter annual and forage crops.*

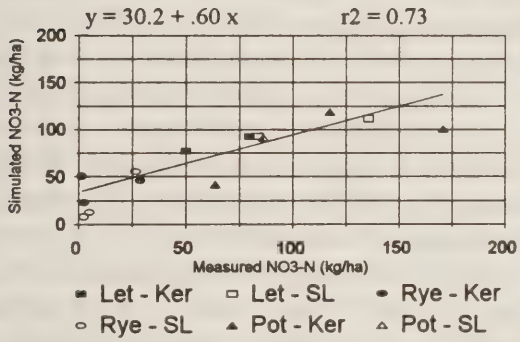


Figure 2. *Simulated vs observed residual soil NO_3-N for a sandy loam (SL) and loamy sand (Ker). NLEAP outputs for lettuce fall 1994 (Let), rye spring 1995 (Rye), and potato fall 1995 (Pot).*

APPROACH: NAL was monitored for the top 0.3 m, 0.3 m - depth of the rooting zone, and depth of the rooting zone to 1.5 m. Simulated values for NAL for fall 1994 after lettuce (Let); spring 1995, after early planted WCR (Rye); and fall 1995, after potato (Pot), were correlated to observed NAL.

RESULTS: Adjustments in model simulations were done since NLEAP did not predict observed patterns of winter annual rye N uptake WRNAU (**Figure 1**). To improve NLEAP predictions of WRNAU, WCR was simulated as an annual forage crop N uptake (AFCN) with repeated harvests. We assigned 85% of the yield to a 1st cut by the first killing frost. A 15% yield was assigned to a 2nd cut from the greenup day to WCR kill. We assigned a 0% yield to a 3rd cut from WRC kill to the end of the run. Results of the AFCN simulations were very close to observed N uptake by the WCR.

The NLEAP sequential model outputs effectively described the simulated NAL for the three soil horizons (0 - 1.5 m), $r^2 = 0.73$ ($P<.001$) (**Figure 2**). NLEAP simulated the effect of WCR in N cycling and in the conservation of soil and water quality. NLEAP is a powerful tool to be used to study long term N fertilizer use efficiency. WCR as a scavenger crop reduced net NO_3-N losses from these systems.

Future Plans: A manuscript about the use of NLEAP sequential model to simulate the effect of WCR on water and soil quality will be published.

[1]USDA-GPSRU, Fort Collins, CO and [2]USDA-NRCS, Area Office, Alamosa, CO

USE OF THE NLEAP SEQUENTIAL MODEL TO ASSESS N-USE EFFICIENCY FOR POTATOES, SMALL GRAINS, AND VEGETABLES

J.A. Delgado and R.F. Follett

PROBLEM: It has been reported that nitrogen management practices in the San Luis Valley (SLV) increase residual soil NO_3-N, increasing the potential NO_3-N available to leach (NAL). The USDA-ARS is using the sequential NLEAP (Nitrate Leaching and Economic Analysis Package) model to assess the N-use efficiency of different cropping systems in the valley and the effect on NAL.

APPROACH: Model simulations are being conducted for 25 sites. The NLEAP sequential model is being calibrated and validated to be used in evaluation of different organic amendments, fertilizer rates, N-fertilizer sources, crop varieties, soil textures, management practices, and other treatments. The model will be used to conduct computer simulations at a series of these sites where there are two and three years of consecutive information.

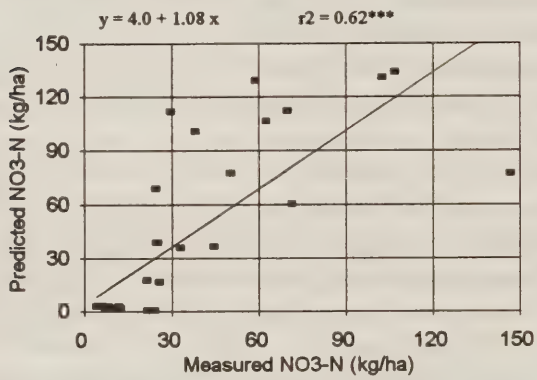


Figure 1. *Predicted vs Observed residual soil NO_3-N for the top 0.3 m*

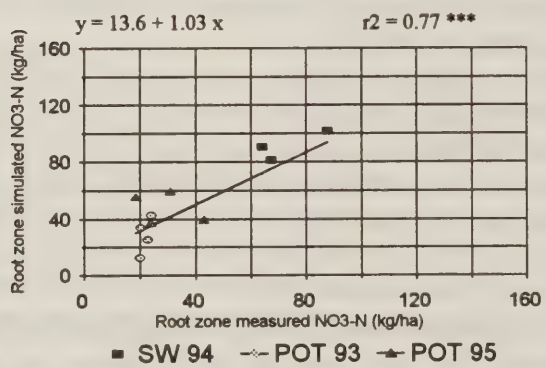


Figure 2. *Three year simulation of predicted vs observed residual soil NO_3-N for the root zone of 1993-potato (POT 93), 1994-spring wheat (SW 94) and 1995-potato (POT 95)*

RESULTS: The NLEAP sequential model appears to be simulating the residual NAL for one year simulations across grains, vegetables and potatoes grown under different management practices (**Figure 1**). The preliminary NLEAP computer simulations on NAL were significantly correlated with observed NAL, r^2=0.62 (P<.001) (**Figure 1**).

Additional preliminary computer simulations suggest that this version of NLEAP effectively predicts multiple years of potato-grain rotation and N cycling (**Figure 2**). The sequential NLEAP model successfully simulated the long term effects that irrigation, N fertilization, agricultural management practices, weather and multiple years of potato grain rotations will have on NAL, r^2 = 0.77 (P<.001) (**Figure 2**).

FUTURE PLANS: The NLEAP sequential model will be used to run simulations of different cropping systems. Final results will be published.

SOIL-C STORAGE WITHIN SOIL-PROFILES OF THE HISTORICAL GRASS LANDS OF THE USA.

R.F. Follett and E.G. Pruessner - Coinvestigators: J. Kimble[1] and S. Samson-Liebig[1]

PROBLEM: Vast reserves and the potential to sequester immense amounts of carbon (C) in soils exists in the historical grasslands of the USA (HG). These soils are important as a source-sink in global C cycling. Large areas within the HG are converted from cropland to the Conservation Reserve Program (CRP). Research indicates that CRP enhances C sequestration, but the magnitude is uncertain as is the importance of C gains or losses at deeper soil-profile depths. Another consideration is that CRP contracts are beginning to expire; millions of hectares of CRP land may return to production. Thus, much of the C that the CRP program helped sequester is at risk to being recycled back to the atmosphere as CO_2.

APPROACH: A collaborative effort is underway with the National Soil Survey Laboratory (NSSL) of the NRCS in Lincoln, NE to collect detailed soil-profile measurements. Use of these data, with STATSGO or other data bases, will allow estimates of soil-C storage in HG soils and the influence of management (cropped vs. CRP vs. native grassland). Soils are sampled by horizon from pits (~ 2m deep) at sites along precipitation and temperature gradients. At every site, a separate pit is sampled for each of the three managements; all pits are in the same map unit and on a similar geomorphic setting, even though soil series may change because of management. Soil-physical, -mineralogical, -micromorphological, and -chemical characterizations are by the NSSL. The Fort Collins laboratory is responsible for measurements of various C pools (i.e. total-organic, identifiable plant material, particulate organic matter, mineral associated, and microbial biomass-C). Isotopic analyses for $^{13}C/^{12}C$ ratios and ^{14}C dating will be done on selected samples to better assess issues related to C-sequestration processes and timing.

RESULTS: Sites have been sampled in CO, NE, IA, TX, MT, MO, and MN and the samples are at various stages of analyses. The results thus far indicate that CRP has resulted in large increases in aggregate stability compared to cropland. For sites in CO, NE, and IA, average aggregate stability for surface soils are 23, 20, and 4 (% <5 mm) in CRP, native, and cropland soils, respectively. There are also increases in organic C in the top 10 cm in CRP versus cropland, though they have not reached the levels of the native soil. Additionally, average soil microbial biomass-C (kg/ha) in the 0-60 cm depth is 28% higher in CRP and 81% higher in native than in cropland soils.

FUTURE PLANS: Field collection of samples will resume this coming spring. The focus at that time will be completing our field sampling at sites in OK and ND.

[1]NRCS, Lincoln, NE

USE OF IMPROVED TILLAGE SYSTEMS TO INCREASE SOIL ORGANIC CARBON AND NITROGEN USE EFFICIENCY IN VERTISOLS IN MEXICO

R.F. Follett and E. Buenger - Coinvestigators: J.V. Castellanos[1] and M. Mora[1]

PROBLEM: Vertisols are widely distributed soils in the world including in parts of the United States. In Mexico, vertisols occupy about one million hectares (2;500,000 acres) and produce about one fourth of the wheat and one fifth of the corn and sorghum. In Mexico, for at least 50 years, crop residues have been burned and the soils deeply and frequently plowed. Long-term records indicate that soil organic carbon (SOC) has been reduced by half of its initial level and loss of the soil organic matter (SOM) has decreased the soil organic nitrogen (N) supplying capacity to about 16 kg N/ha per crop. Thus, these soils have lost much of their capacity to mineralize N for crop production, to support an active microbial biomass for nutrient retention and cycling, to retain applied pesticides, and they also have a lower water holding capacity than do soils with higher levels of SOM. An important additional problem is that leaching of nitrates from applied fertilizer N into groundwater decreases the quality of the water pumped from wells that are used as a source of drinking water for large numbers of rural residents. Nitrate in groundwater under vertisols in areas near Celaya, MX range from 5 to 40 ppm NO_3-N and our initial data indicate these levels are increasing.

APPROACH: This project was funded by the Research and Scientific Exchanges Division of USDA/FAS/ICD. A collaborative effort is underway to demonstrate that soil organic matter levels can be increased in the vertisols of the center of Mexico by the use of no-till for wheat-corn and wheat-bean cropping sequences. $^{15}N/^{14}N$ and $^{13}C/^{12}C$ isotope-ratio technology will be used to study the effect of traditional versus improved tillage on N and SOC dynamics. The experiment consists of 4 replications of 5 tillage treatments and 3 fertilizer rates on 10 m by 10 m plots. Fertilizer rates are 0, 150, and 300 kg N/ha applied to both irrigated wheat and irrigated corn (2 crops/year). Tillage treatments are wheat-corn with no-till, wheat- corn with plowing, wheat-corn with burning of the residues, wheat-bean with no till, and wheat-bean with plow tillage. The study was begun in 1993, thus there have been 4 crops already grown with this years crops being the 5^{th} and 6^{th}.

RESULTS: Forty micro plots were fertilized with ^{15}N and 10 remained unfertilized. The micro-plot size is 1.8 by 2.8 m and the ^{15}N fertilizer and its fate will be followed through several crop cycles. The first winter wheat crop for the ^{15}N component of the study is planted and growing. Archived soil samples have been located to allow follow up on the $^{13}C/^{12}C$ isotope-ratio part of the study following at least another year of plant labeling of the soil for determination of treatment effects on plant residue contributions to the soil-C pool.

FUTURE PLANS: The main plots will be harvested for yield and replanted to the second crop. Plants and soil samples will be collected for laboratory analyses.

---

[1]Campo Experimental Bajio Celaya - San Miguel Allende, MX

SOIL MICROBIAL-BIOMASS AND ORGANIC-C DYNAMICS DURING A LONG-TERM INCUBATION

R.F. Follett and E.G. Pruessner - Coinvestigator: E.A. Paul[1]

PROBLEM: To better understand the pools wherein total soil-organic carbon (SOC) is sequestered. Modeling can be based upon a three-pool approach in predicting carbon (C) turnover. Thus, it is important to be able to predict both the sizes of the C-pools and the mean residence time (mrt) that SOC remains in each of pools.

APPROACH: A long-term incubation (853 days), with no added substrate, was run using soil from 2 long-term studies in CO and NE. Fifty g samples of soil were placed in glass snap-cap vials and brought to -0.05 MPa potential with distilled water by weight. Duplicate samples were placed in separate air-tight glass containers (1.89 L). Each container had an alkali trap (1 M NaOH) placed in it to determine CO_2 evolution. Samples were incubated in the dark at a constant temperature of 30°C. Alkali traps were changed and CO_2 determined at 1, 2, 4, 10, 21, 39, 64, 79, 90, 122, 160, 171, 202, 265, 322, 378, 442, 522, 553, 634, 720, 748, 842, and 853 days. Soil microbial biomass (SMB) was measured at days 10, 79, 161, 322, and 842. SOC was measured for these same days, but not at day 79. SMB was determined by a chloroform fumigation procedure. SOC was determined using a Carlo Erba C/N analyzer. Multiple regression analyses of the data were used to determine c1 (active) and c2 (passive) pool sizes and their mean residence times. The c3-pool sizes and their mrt's (> 1000 yr) were based upon amounts of nonhydrolyzable SOC (hot 6N HCl) and its ^{14}C age.

RESULTS: After 853 days, SOC was 61 to 73 (avg 67) %, and SMB was 10 to 29 (avg 17) %, of original (day 0) levels. Soil from plowed wheat-fallow had the lowest initial and final SOC and SMB levels and soil from undisturbed sod had the highest levels; no-till wheat-fallow was intermediate. Initial SOC levels decreased from between 13 to 30 g/kg to between 6 and 20 g/kg after 853 days. Initial SMB levels ranged from 280 to 1580 µg/g and decreased to 40 to 230 µg/g after 853 days. Half-life ($t_{½}$) of SMB averaged 360 days across all soils and treatments. Fraction of SMB in the SOC decreased from between 2.8 and 5.3 percent to about 0.6 to 1.0 % by day 853. Because SMB decreased more rapidly than SOC, the SMB/SOC ratio may be a more sensitive measure of SOC response to management than are either of the individual measures. The calculated laboratory mean residence times ranged from 25 to 77 days for the c1 pool and from 3.6 to 6.6 years for the c2 pool.

FUTURE PLANS: The SMB will be evaluated as an estimate for c1 and mrt1. Results of $\delta^{13}C$ measurements on the field soils will be calculated to provide another estimate of the c2 pool sizes and their mrt's. Completion of data analyses and its publication will then proceed.

[1]Crop and Soil Sciences, Michigan State University, E. Lansing, MI

BIOREMEDIATION OF HIGH NITRATE WELL WATER BY THE USE OF INNOCUOUS VEGETABLE OIL

W.J. Hunter and R.F. Follett

PROBLEM: Nitrate in groundwater is the most common water quality problem in the world. In the United States nitrate contamination is greatest in sections of the Great Plains and west. High nitrate levels and the difficulty of removing nitrate from water have forced communities to abandon wells and find new sources of water. Nitrate is relatively nontoxic but it is transformed to nitrite following ingestion. In infants, blood oxygen transport can be impaired by nitrite; in adults, carcinogenic nitrosamines may form. Innocuous oils can remove nitrate from water. Usually, it is the absence of a carbon source that limits microbial denitrification of groundwater. Oil provides the carbon. Oil might be injected around a well or the mixing of oil with sand and gravel to form a filter for the removal of nitrate from water. Also, oil could be injected into the ground to form a barrier to contain a nitrate plume. Unfortunately, denitrified water may be of poor quality.

APPROACH: Vegetable oil, 10g, was applied to sand and the sand used to pack a 2.6 by 35 cm laboratory soil column. The oil provides an organic zone through which the water flows. Water containing 100 ppm nitrate was pumped through the columns. Soft, moderate, hard, and very hard waters were used. Columns effluents were monitored to determine the quality of the effluent water. A secondary treatment process was used to improve the quality of the effluent water.

FINDINGS: A *D. magna* toxicity test indicated that no substances of concern were present in effluents from the denitrification reactors. Water hardness did not influence the denitrification process nor did we observe a correlation between water hardness and the quality of effluent from the denitrification reactor. Effluent waters coming from the denitrification reactor, were free of nitrate but chemical oxygen demand (COD), suspended solids (TSS), and turbidity (NTU) values were high while dissolved oxygen (DO) was low and H_2S was detected. The coupling of the denitrification reactors with the granular activated charcoal and sand (GAC-sand) filters improved the water. Mean COD dropped from 62 to 28 mg/l, a decline of 55%; total solids dropped to 0.8, a decline of 90%; mean turbidity decreased by 90% to 2.0 NTU; and dissolved oxygen increased by 153%; redox (platinum electrode) increased from -345 to +256 mV; and the H_2S was eliminated. The GAC-sand filter also altered the pH of the water increasing it from 7.4 to 8.4. The GAC-sand filter reduced bacteria in the effluent stream by an order of magnitude. Heterotrophic bacteria in denitrifier reactor and GAC-sand filter effluents were 5×10^7 and 5×10^6 colony forming units per ml, respectively. The above water quality measurements clearly demonstrate that a relatively simple GAC-sand filter system can markedly improve the quality of effluents from the denitrification reactor.

FUTURE PLANS: Future work will be directed at 1) expanding the laboratory data obtained in CY 96, 2) preparing the laboratory data for publication, and 3) developing an "artificial aquifer" or large scale laboratory model for future studies with the vegetable oil.

EMEDIATION OF WATER CONTAINING AROMATIC AND ALIPHATIC COMPOUNDS USING VEGETABLE OIL IN SOIL COLUMNS

W.J. Hunter

PROBLEM: Halogenated aromatic and aliphatic compounds are used in the fabrication of dyes, explosives, pharmaceuticals, herbicides and insecticides. Soil and water contamination has resulted from the use and improper disposal of these compounds as well as from spills associated with the manufacture and transport of these compounds. Agriculture has been a major contributor to the problem. The cleanup and detoxification of contaminated soils and waters must utilize bioremediation otherwise, the environmental and economic costs associated with the cleanup will be enormous.

Innocuous vegetable oil might be useful in the biodegradation of these compounds. In most subsoils and aquifers microbial activity is limited by the amount of carbon present; respiratory term electron acceptors such as oxygen or nitrate are often available. Vegetable oil will provide a carbon source for native microorganisms, stimulating microbial activity and lowing the redox as oxygen is consumed. Many pesticides are more amenable to degradation under anoxic conditions; picloram as well as 2,4-D and 2,4,5-T undergo reductive dehalogenation under anaerobic conditions. Also, organics in the water, because of their large partitioning coefficients, partition into and concentrate in the oil phase. Thus, the oil should act to concentrate hydrophobic pesticides etc. It is hypothesized that anaerobic degradation of concentrated hydrophobic pesticides will take place at the oil-water interface.

APPROACH: Columns were 2.6 x 35 cm sand filled glass tubes pumped with water containing metolachlor. A vegetable oil emulsion was injected onto the columns at the start of each study. Column temperature was 15°C. Control columns received no oil while treatment columns received 2 ml of oil. Study 1: Oil was injected into the influent port of the treatment columns and water containing 195 ppm metolachlor was pumped through the columns. After 10 days the columns were disassembled and the sand core extracted with solvents. Study 2: Oil was coated onto the sand of the treatment columns and water containing 20 ppm metolachlor was pumped through control and treatment columns for 8 weeks.

RESULTS: Study 1: With the controls metolachlor, in small amounts, was uniformly distributed throughout the sand core. With the treatment columns >95% of the metolachlor recovered from the columns was concentrated in the first five centimeters of the sand core, the region previously shown to contain the injected oil, showing that oil will act to concentrate the pesticide. Study 2: For the first week the treatment columns effectively removed metolachlor from the water. However, after the first week the treatment columns failed to remove the metolachlor from the water.

FUTURE PLANS: No future work planned.

DNA SEQUENCE OF AN OPERON CONTAINING THE REGION RESPONSIBLE FOR ENHANCED NITROGEN FIXATION BY *BRADYRHIZOBIUM JAPONICUM*

W.J. Hunter - Coinvestigator: L.D. Kuykendall[1]

PROBLEM: A soybean inoculant that exhibits increased nitrogen fixation was developed (Appl. Environ. Microbiol. 56:2399-2403, US Patent #5,021,076) and is now a commercial product. The strain of *Bradyrhizobium japonicum* used in the inoculant fixes more nitrogen because it is able to form more root nodules. The physiological basis for the improved nodulation is not known. An understanding of the genetic change that caused this improved nodulation might lead to the development of additional or better strains. The improved *B. japonicum* strain is a prototrophic revertant of a tryptophan (*trpC*) auxotroph. Evidence indicated that genetic changes in this region impact symbiotic nodulation. Bradyrhizobia that are resistant to 5-methyltryptophan show altered nodulation (Lett. Appl. Microbiol. 18:340-342). Mutant bradyrhizobia (tryptophan auxotrophs) often cannot nodulate normally (Soil Biol. Biochem. 21:779-782). Deletion mutants with lesions in the *trpCD* region are unable to nodulate (Soil Biol. Biochem. 27:1035-1039).

APPROACH: A 2,764 base pair *Bam*HI-*Hin*dIII DNA fragment specifying the *tryDC* genes of wild-type *B. japonicum* I-110 was sequenced.

RESULTS: Three open reading frames within a single operon were identified. Sequence comparisons of the predicted amino acid product indicate that the first two open reading frames are the *trpD* and *trpC* genes, respectively. Genes that code for anthranilate-5-phosphoribosyl pyrophosphate phosphoribosyl transferase and indole glycerol phosphate synthase (IGPS), respectively. The *trpC* product contained the IGPS signature motif, LIAEVKKASPSKGLI. A search for amino acid alignment of the predicted product of the third open reading frame revealed that this polypeptide had a 58% identity over 155 amino acids with the *moaC* gene of *E. coli*. The hypothetical *B. japonicum moaC* product has 171 amino acids and a molecular weight of 17,966 Daltons. At the present time nine amino acid sequences that show high identity with the *E. coli moaC* protein are available. Within these nine sequences there are two highly conserved amino acid motifs, LIPLCH and TGVEMEAL, that are likely to be important functionally or structurally. Structural predictions suggest that the TGVEMEAL motif is located at the end of a membrane associated helix with the TGV portion falling outside of the helix and the EMEAL portion within the helix. The protein product of *moaC* is involved in the biosynthesis of a molybdopterin cofactor. As these genes all exist in a single operon deletions in the upstream *trpD* or *trpC* genes would influence the transcription of the *moaC* gene. Therefore it may be that it is a *moaC* product rather than a *trpD* or *trpC* product that influences nodulation. The GenBank accession number for the sequence is U79771.

FUTURE STUDIES: Genes from the improved inoculum need to be sequenced to determine how this strain differs from the wild-type strain. Dr. Kuykendall will lead the investigation.

---

[1]ARS Beltsville, MD

NO, N_2O, AND CH_4 EXCHANGE DURING N TRANSFORMATIONS IN SOIL

G.L. Hutchinson, M.F. Vigil, J.A. Morgan, and G.E. Schuman - Co-Investigator: J.W. Doran[1]

PROBLEM: NO, N_2O, and CH_4 are radiatively, chemically, and ecologically important trace atmospheric constituents. Microbial processes in soil are a major source of the NO and N_2O and both a source and sink for CH_4, so it is essential to understand the gases' soil-atmosphere exchange and, if needed, to develop mitigation technologies. Short-term exchange rates of the three gases have been measured under a variety of soil and climatic conditions around the world, but longer-term studies of seasonal-to-interannual exchange are conspicuously absent from the literature. Assessing the contribution of the net soil source of each gas to its global atmospheric budget is further confounded by immense temporal and spatial variability in the exchange rates and by the existence of multiple biotic and abiotic soil sources and sinks of the gases, each subject to a different set of controllers.

APPROACH: Our overall goal is to capture field-measured exchange rates of the gases in terms of their basic physical, chemical, and biological controllers. Dependence of the fluxes on these controllers will be characterized in controlled laboratory soil incubation studies and then described using simulation models parameterized by variables observable across different scales.

RESULTS: We completed second-year field studies of plant species effects on trace gas fluxes in the shortgrass steppe and submitted the data for publication. We also completed a long-term year-around comparison of NO and N_2O emissions from grazed and ungrazed shortgrass steppe, which suggests that NO emission is a key regulator of long-term grassland productivity. Publication of remaining data from studies of tillage, crop, and fertilization effects on trace gas exchange from CRP plots near Akron, CO was delayed to complete its soil water modeling component. Use of CrO_3-coated pumice to oxidize NO to NO_2 prior to its luminol-based detection minimized occurrence of apparent shifts in detector response in the field, but achieving consistent high oxidation efficiency also required improving the instrument's sample air dryer. We secured 2-year funding to include the effects of grazing and elevated CO_2 in this work and submitted another proposal to determine trace gas losses from swine waste applied through sprinklers to agricultural crops in eastern Colorado.

FUTURE PLANS: Objectives of the funded proposal will be addressed in field and growth chamber experiments using extensive sampling, isotopic tracers, and modeling exercises to determine how grazing, elevated CO_2, plant species, and soil N availability influence C and N sequestration in surface soil by monitoring above- and below-ground partitioning of plant C and N and its passage through the litter and soil microbial biomass into increasingly more stable fractions of soil organic matter. Trace gas objectives superimposed on these studies include plans (1) to improve existing schemes for describing the dependence of NO and N_2O exchange on soil N availability, (2) to develop a better method for modeling event-driven NO and N_2O emission pulses, and (3) to field test a proposed procedure for weighting the nitrification and denitrification modules of existing models.

---

[1]USDA-ARS, Lincoln, NE

PERFORMANCE OF CHAMBERS FOR MEASURING TRACE GAS EXCHANGE

G.L. Hutchinson - Co-Investigators: G.P. Livingston[1], R.W. Healy[2], and R.G. Striegl[2]

PROBLEM: Chambers play a critical role in research concerning surface-atmosphere trace gas exchange, so understanding their performance and limitations is essential to properly interpret published trace gas budgets, to develop and validate trace gas exchange models, and to conduct experimental studies of trace gas exchange processes. Deployment of either a steady-state or non-steady-state chamber inherently perturbs its underlying vertical and horizontal soil gas concentration gradients, thereby altering the surface-atmosphere gas flux that the chamber was intended to measure. Failure to account for that perturbation results in the potential for significant measurement error.

APPROACH: We use a numerical gas diffusion model to examine steady-state and non-steady-state chamber feedback processes as a function of atmospheric interfacial layer depth, headspace mixing, soil transport properties, and trace gas source/sink characteristics. It differs from other models used to investigate chamber performance in that it is 3-dimensional, uses a shorter time step, and includes the chamber headspace in the simulated domain. We are also developing a nonlinear regression approach to trace gas flux estimation from non-steady-state chamber concentration data that employs a recently derived analytical solution of the 1-dimensional time-dependent gas diffusion equation.

RESULTS: Using the improved understanding of chamber function and performance gained from previous simulations, we performed additional model runs to define optimum chamber design and deployment protocols. We found that (1) including provision for forced headspace mixing in the chamber design (e.g., a fan) is almost always unnecessary and sometimes undesirable, (2) elaborate precautions practiced by some users for achieving an air-tight seal of the chamber top to its permanent base are usually unnecessary, (3) depending on chamber deployment time and soil gas permeability, the chamber base must be inserted into the soil from 1 cm to as much as 20 cm to avoid unacceptable error due to lateral diffusion, (4) even small displacement of the trace gas gradient in soil by a momentary pressure disturbance during chamber placement or headspace sampling influences the chamber's performance throughout the deployment period, (5) sequential measurements on the same chamber base must be spaced as much as several hours apart to allow the underlying trace gas gradient to recover from feedback effects of the previous deployment, and (6) a steady-state chamber does not recover from its initial non-steady-state condition within a reasonable deployment period.

FUTURE PLANS: Of the two remaining manuscripts planned for describing the simulation results, one is in ARS peer review and the last is in junior author review. As time permits, we plan additional experimental verification of the simulation results using a chamber deployed over a uniform shallow layer of sand (or soil) suspended above a well-mixed reservoir that is continuously flushed by an airstream with constant flow rate. The measured difference between the fluxes of trace gas into and out of the reservoir provides an independent measure of the steady-state flux across the soil surface.

[1]University of Vermont, Burlington, VT; [2]USGS Water Resources Division, Denver, CO.

EVENT-DRIVEN PULSES OF CO_2, NO, AND N_2O EMISSIONS FROM SOIL

G.L. Hutchinson - Co-investigator: D.C. Reicosky[1]

PROBLEM: A large pulse of CO_2, NO, and N_2O evolution often immediately follows wetting of very dry soil. The pulse is too large to be explained by water's well-defined effects on transport in soil, and its cause remains unclear. Similar pulses sometimes occur following rapid warming of soil previously exposed to near-freezing or subfreezing temperatures, following tillage of partially compacted soil, and possibly following sudden removal of other environmental limitations on microbial growth and metabolism. Emission rates during such an event may be up to 1000-fold higher than rates preceding or following the pulse, so the quantity of soil C or N lost during its brief duration may exceed the total amount emitted during the much longer period before the soil becomes predisposed to support another emissions pulse in response to the next perturbation.

APPROACH: Both experimental and modeling approaches are being used to examine the relative contributions of biological vs. physical/chemical mechanisms to each emission pulse as a function of the gas species and the pulse driver. A separate combination of field measurements and controlled laboratory soil incubation studies is designed to test the hypothesis that the biological contribution often results from decoupling consecutive reactions mediated by separate microorganisms with different sensitivities to the offending environmental limitation.

RESULTS: Field and laboratory studies of the NO and N_2O emission pulses that occur in response to wetting dry soil suggest that (1) the wetting response depends strongly on antecedent conditions; (2) the wetting response is largely independent of the size of its triggering precipitation or irrigation event; (3) there appears to be an interaction between the exposure time and exposure concentration required to establish conditions prerequisite for supporting a pulse following the next addition of water, i.e., the degree of dryness that must be attained may not be absolute; and (4) it remains unclear whether the wetting response is influenced directly by inorganic N availability. We presented reviews of pulsing's relation to both fine-scale and coarse-scale existing models of gaseous N oxide exchange at separate international conferences and submitted them for publication. In addition, we completed laboratory evaluation of a proposed procedure for separating nitrifier- from denitrifier-based NO and N_2O exchange in the field, including the emission pulses.

FUTURE PLANS: Using temporary (2-year) ARS Global Change Research funding, we created a postdoctoral position to perform controlled laboratory soil incubation experiments that use selective microbial inhibitors and independent manipulation of the concentrations and transport rates of gas-phase and solution-phase reactants and products of microbial C and N transformations in soil to characterize the contributions of these and other processes to the pulse of CO_2, NO, and N_2O evolution following temperature, wetting, and physical disturbances. Results will be confirmed in the field before incorporation into existing trace gas exchange models.

---

[1]USDA-ARS, Morris, MN.

METHANE, NITROUS OXIDE AND NITRIC OXIDE FLUXES IN THE COLORADO SHORTGRASS STEPPE

A.R. Mosier - Coinvestigators: W.J. Parton[1], D.S. Ojima[1], and D.S. Schimel[2]

PROBLEM: Knowledge of the role of agricultural and rangeland systems on the atmospheric concentrations of trace gases CH_4, N_2O, and NO_x is limited. Since these gases are involved in local and regional atmospheric oxidant concentrations, global atmospheric warming and stratospheric ozone depletion, understanding of the impact of land management and land use change on the soil-atmosphere exchange of these trace gases are needed to understand the changing atmospheric concentrations of these trace gases and to provide research based information to local, regional, national and international policy makers.

APPROACH: In 1990 a program was initiated to measure the soil-atmosphere exchange of CH_4 and N_2O in a variety of systems within the Colorado shortgrass steppe and other regional and more widespread ecosystems. In 1994 quantification of NO_x fluxes was integrated into the program. The program will continue as an integral part of the shortgrass steppe long term ecological research program (NSF/LTER) and earth observation system (NASA/EOS) and data are being incorporated into the data sets being accumulated by the U.S. Trace Gas Network activity that are being used in modeling the local, region and global impact of trace gases.

RESULTS: From our measurement program we have assessed intersite, interannual variations in trace gas fluxes in the shortgrass steppe. We found that wintertime fluxes contribute 20-40% of the annual N_2O emissions and 15-30% of CH_4 consumption at all of the measurement sites. Nitrous oxide emission maxima were frequently observed during the winter and appeared to result from denitrification when surface soils thawed. Generally, site mean annual flux maxima for CH_4 uptake corresponded to minimum N_2O fluxes and vice versa, which supports the general concept of water control of diffusion of gases in the soil and limitations of soil water content on microbial activity. We also observed that pastures that have similar use history and soil texture show similar N_2O and CH_4 fluxes, as well as similar seasonal and annual variations. Sandy loam soils fertilized with nitrogen 5-13 years earlier consumed 30-40% less CH_4 and produced more N_2O than unfertilized pastures. In contrast, the N addition 13 years earlier does not affect CH_4 uptake but continues to increase N_2O emissions in a finer-textured soil. We found that conversion of grassland to croplands typically decreased the soil consumption of atmospheric CH_4 and increased the emission of N_2O. Fields converted to winter wheat production about 70-y earlier consumed about 50% less CH_4 produced about double the amount of N_2O than the native grassland. A wheat field that was reverted back to grassland in 1987 continued to exhibit annual CH_4 uptake and N_2O emission rates similar to the wheat fields. Another wheat field that was returned to grassland in 1939 exhibited the same CH_4 and N_2O flux rates as comparable native pastures.

FUTURE PLANS: The long term studies to further understand N biogeochemistry and interannual variability of trace gas fluxes within the shortgrass ecosystem will continue.

[1]NREL, Colorado State University and [2]NCAR, Boulder, CO

SHORTGRASS STEPPE ECOSYSTEM DYNAMICS AND TRACE GAS EXCHANGE UNDER ELEVATED CO_2

A.R. Mosier and J.A. Morgan - Coinvestigators: W.J. Parton[1], D.S. Ojima[1], and D.G. Milchunas[2]

PROBLEM: Atmospheric CO_2 concentrations have been rising in the past few decades at historically unprecedented rates, and are projected to continue rising. No field studies have addressed how elevated CO_2 might impact the shortgrass steppe of the western United States. Based on experiments in other ecosystems, elevated CO_2 is expected to enhance short-term productivity of the grassland but on the long-term CO_2 enrichment may elicit significant soil microbiological responses that will determine the capability of the grassland to respond to CO_2. The CO_2-induced alterations in soil microbial activities will also affect the exchange of CH_4, NO and N_2O within the grassland in unknown ways.

APPROACH: The research we will initiate couples the use of large, open-top chambers for field CO_2 enrichment studies with soil N cycling and trace gas flux measurements. We have three basic objectives in this research. The first is to determine the impact of doubling CO_2 in the SGS on photosynthesis, productivity, water and N use efficiency, plant water relations, and C and N allocation in above- and below ground parts of two dominant grass species, one C_4 and one C_3 photosynthetic pathway. The second is to determine the impact of doubling CO_2 on soil water and N dynamics. The third goal is to incorporate knowledge gained from the studies into simulation models that will allow for realistic extrapolation through time and space of soil moisture, nutrient cycling, plant productivity, and overall ecosystem response.

RESULTS: During the year the open-top chamber systems were constructed and tested so that CO_2 enrichment can begin in the spring of 1997. During the construction period we conducted several experiments and sets of measurements to use as baseline information and to test the effect of a the small N addition planned for the CO_2 enrichment study sites so that system N utilization could be quantified. We found, from additions of 0.5 g N m^{-2} of ammonium nitrate, that this rate of N addition neither altered the emission rates of NO or N_2O nor the rate of soil consumption of atmospheric CH_4 through a 6-month measurement period. In assessing the variability of N mineralization across the study site we found that soil N mineralization rates within clumps of C_4 or C_3 grasses did not differ but net N mineralization rates between grass clumps were higher than within grass clumps. After measuring the peak standing biomass of the three major grass species within our study sites we found that the biomass production of these grasses across the different CO_2 enrichment locations were not distinguishably different.

FUTURE PLANS: The CO_2 enrichment study is to begin in the spring of 1997. We anticipate continuing the study for at least 5 years after initial enrichment.

---

[1]NREL, and [2]Rangeland Ecosystem Science, Colorado State University, Fort Collins, CO

SOIL-PLANT-NUTRIENT RESEARCH UNIT

Publications

Benjamin, J.G., L.R. Ahuja, L.K. Porter and H.R. Duke. 1996. Nitrogen leaching with alternate and every furrow irrigation and fertilizer bands. Agron. Abstr. 88:277.

Castellanos, J.Z., C. Hernandez, J. Martinez-Saldana, E. Romero-Fierro, and R.F. Follett. 1996. Nitrates in groundwater in Northern and Central Mexico. Agron. Abstr. 88:29.

Cole, C.V., C. Cerri, K. Minami, A.R. Mosier, Rosenberg, D. Sauerbeck, et al. 1996. Agricultural options for mitigation of greenhouse gas emissions. pp. 745-771. *IN* Climate Change 1995. Impacts, Adaptations, and Mitigation of Climate Change, R.T. Watson et al. (Eds.). Cambridge University Press, Cambridge.

Delgado, J.A. and R.F. Follett. 1996. Sap test to determine NO_3-N concentrations in aboveground biomass of winter cover crops. Agron. Abstr. 88:241.

Delgado, J.A. and A.R. Mosier. 1996. Mitigation alternatives to decrease nitrous oxide emissions and urea-nitrogen loss and their effect on methane flux. J. Environ. Qual. 25:1105-1111.

Delgado, J.A., R.F. Follett, J.L. Sharkoff, and M.K. Brodahl. 1996. Nitrogen content and indices of selected crops grown in the San Luis Valley of south central Colorado and their use in simulating crop N uptake and soil N transformations. NLEAP FACTS Sheet 4/96. USDA-ARS and USDA-NRCS.

Delgado, J.A., M.K. Brodahl, M.J. Shaffer, R.F. Follett, and J.L. Sharkoff. 1996. A list of definitions to consider when using the NLEAP model to evaluate N management practices in soils containing coarse fragments. NITROGEN MANAGEMENT NLEAP FACTS Sheet 5/96. USDA-ARS and USDA-NRCS.

Delgado, J.A., A.R. Mosier, D.W. Valentine, D.S. Schimel, and W.J. Parton. 1996. Long term ^{15}N studies in a catena of the shortgrass steppe. Biogeochemistry 32:41-52.

Delgado, J.A., R.F. Follett, J.L. Sharkoff, R.R. Riggenbach, and R.T. Sparks. 1996. Preliminary assessment of N-uptake and NO3-N accumulation of winter cover crops and their effect on soil and water quality in the San Luis Valley of Colorado. 13th Annual Potato/Grain conference. (Monte Vista, Colorado, February 13 - 15) Conference Proceedings pp 5.

Delgado, J.A., A.R. Mosier, R.H. Follett, R.F. Follett, D. Westfall, L. Klemedtsson, and J. Vermeulen. 1996. Effect of N management on N_20 and CH_4 fluxes and N recovery in an irrigated mountain meadow. Nutrient Cycling in Agroeconomics. 46:127-134.

Doran, J.W., A. Kessavalou, G.L. Hutchinson, M.F. Vigil, and A.D. Halvorson. 1996. Influence of cropping/tillage management on soil fertility and quality of former CRP land in the central High Plains. p. 205-209. *In* J.L. Havlin (ed.). Great Plains Soil Fertility Conf. Proc., Vol. 6. Potash & Phosphate Institute, Manhattan, KS.

Epstein, H.E., I.C. Burke, A.R. Mosier, and G.L. Hutchinson. 1996. Plant species effects on trace gas fluxes in the shortgrass steppe. Agron. Abstr. p. 304.

Epstein, H.E., I.C. Burke, A.R. Mosier, and G.L. Hutchinson. 1996. Plant species and soil texture effects on trace gas fluxes in the shortgrass steppe. Bull. Ecol. Soc. of Am. 77:131.

Epstein, H.E., I.C. Burke, A.R. Mosier, and G.L. Hutchinson. 1996. Plant species and soil texture effects on trace gas fluxes in the shortgrass steppe. Ecol. Bull. 77(S):130.

Follett, R.F. 1996. ARS biogeochemical dynamics research, an overview. pp. 13-25. *IN* D.G. DeCoursey and V. Ferreira (eds). Global Change and Agriculture: Soil, Water, and Plant Resources Volume III. USDA/ARS Global Change Research Program.

Follett, R.F., J. Arnold, M.K. Brodahl, J. Cipra, P. Doraiswamy, T. Elliott, D.A. Farrell, I. Flitcroft, K. Killian, K. Paustian, R. Srinivasan, and S. Waltman. 1996. Determination of Agroecozones in the continental United States. Evaluation Study Report (funded on 23 January, 1996 and completed report submitted on April 24, 1996 to Dr. Karl N. Stauber, USDA Under Secretary for Research, Education, and Economics). 168 p.

Follett, R.F., E.A. Paul, and E.G. Pruessner. 1996. Soil microbial-biomass and organic-C dynamics during a long-term incubation. Agron. Abstr. 88:219-220.

Freney, J.R., M.B. Peoples, and A.R. Mosier. 1995. Efficient use of fertilizer nitrogen by crops. Food & Fertilizer Technology Center Extension Bulletin 414, Taipei City, Republic of China on Taiwan, 13 p.

Grunes, D.L., R.F. Follett, S.L. Dallyn, G.A. Pearson, G.V. Richardson, and C.A. Sancherico. 1996. Factors affecting concentrations of Mg, Ca, and K in vegetable crops. Agron. Abstr. 88:255.

Healy, R.W., R.G. Striegl, T.F. Russell, G.L. Hutchinson, and G.P. Livingston. 1996. Numerical evaluation of static chamber measurements of soil-atmosphere gas exchange: identification of physical processes. Soil Sci. Soc. Am. J. 60:740-747.

Hunter, W.J. and R.F. Follett. 1996. Use of innocuous oils to bioremediate groundwater contaminated with nitrate. Am. Soc. Microbiol. Abstr. p. 431.

Hunter, W.J. and R.F. Follett. 1996. Cleaner Well Water. Land and Water Magazine. Fort Dodge, IA. 40 (2):49.

Hutchinson, G.L., and C.E. Andre. 1996. Luminol-based detection of NO in chamber air: dependence on sample humidity and CrO_3 converter support. Agron. Abstr. p. 236.

Hutchinson, G.L., and C.E. Andre. 1996. Dependence of the Scintrex CrO_3 converter on sample relative humidity. p. 36. *In* Abstr. Int. Workshop on NO_X Emission from Soils and its Influence on Atmos. Chem., Tsukuba, Japan.

Hutchinson, G.L., G.P. Livingston, R.W. Healy, and R.G. Striegl. 1996. Performance of chambers for measuring surface-atmosphere trace gas exchange. Ecol. Bull. 77(S):210.

Hutchinson, G.L., M.F. Vigil, J.W. Doran, and A. Kessavalou. 1996. Modeling the net microbial production and soil-atmosphere exchange of gaseous NO_X. p. 11. *In* Abstr. Int. Workshop on NO_X Emission from Soils and its Influence on Atmos. Chem., Tsukuba, Japan.

Keerthisinghe, D.G., X.J. Lin, Q.X. Lou, and A.R. Mosier, A.R. 1996. Effect of encapsulated calcium carbide and urea application methods on denitrification and N loss from flooded rice. Fert. Res. 45:31-36.

Kessavalou, A., J.W. Doran, A.R. Mosier, and R.A. Drijber. 1996. Carbon dioxide, nitrous oxide and methane fluxes following tillage and wetting. Agron. Abstr. p. 239.

Kuykendall, L. D. and W.J. Hunter. 1006. Complete nucleotide sequence analysis of a symbiotically essential Bradyrhizobium japonicum operon that consists of trpD, trpC, and a moaC-like gene. Abstracts of the Annual Meeting of the American Society for Microbiology. p. 484.

Kuykendall, L. D. and W.J. Hunter. (GenBank Sequence Submission). Bradyrhizobium japonicum anthranilate phosphoribosyl transferase (trpD), indole-3-glycerol-phosphate synthase (trpC) and molybdopterin cofactor biosynthesis enzyme (moaC-like) genes, complete cds. National Institute of Health, National Center for Biotechnology Information, GenBank Accession:U79771. 1997.

Martin, R.E, M.C. Scholes, E.A. Holland, A.R. Mosier, D.S. Ojima, and W.J. Parton. 1996. Controls on annual Nox emissions from soils in the Colorado shortgrass steppe. Ecolo. Soc. Am. Abstr. p. 284.

Mosier, A.R., M. Keller, and J.A. Delgado. 1996. NO and N_2O emissions from a limed and unlimed acid Oxisol. International Workshop on NO_x Emissions from Soils. Abstract. p. 42.

Mosier, A.R., W.J. Parton, D.W. Valentine, and D.S. Schimel. 1996. Long-term impact of N-fertilization on N_2O flux and CH_4 uptake in the Colorado shortgrass prairie. Proceedings of the 9th N Workshop, Braunschweig Germany. 9:511-514.

Mosier, A.R., R.E. Martin, M.C. Scholes, D.S. Ojima, W.J. Parton, and D.S. Schimel. 1996. Long-term impact of N-fertilization on NO and N_2O flux in the shortgrass prairie. International Workshop

on NO_x Emissions from Soils. Abstract p. 41.

Mosier, A.R., W.J. Parton, D.W. Valentine, D.S. Ojima, D.S. Schimel, and J.A. Delgado. 1996. CH_4 and N_2O fluxes in the Colorado shortgrass steppe: I. Impact of landscape and nitrogen addition. of

Mosier, A.R., J.M. Duxbury, J.R. Freney, O. Heinemeyer, and K. Minami. 1966. Nitrous oxide emissions from agricultural fields: Assessment, measurement and mitigation. Plant and Soil 181:95-108.

Mosier, A.R., V.L. Cochran, J.A. Delgado, D.W. Valentine, and W.J. Parton. 1996. Methane and nitrous oxide fluxes in soils and current studies in subarctic, temperate and tropical grasslands. pp. 43-64. *IN* D.G. DeCoursey and V. Ferreira (eds.). Global Change and Agriculture: Soil, Water, and Plant Resources Volume III. USDA/ARS Global Change Research Program.

Newkirk, B., D.S. Ojima, and A.R. Mosier. 1996. Integrated data base for trace gas flux estimates. Bull. Ecol. Soc. Am. 77:324.

Parton, W.J., A.R. Mosier, D.S. Ojima, D.W. Valentine, D.S. Schimel, K. Weier, and A.E. Kulmala. 1996. Generalized model for N_2 and N_2O production from nitrification and denitrification. Global Biogeochem. Cycl. 10:401-412.

Porter, L.K., R.F. Follett, and A.D. Halvorson. 1996. Plant N-15 uptake in a wheat-sorghum-fallow-wheat sequence under no-till in the semi-arid Great Plains. Agron. J. 88:750-757.

Porter, L.K. and E.D. Buenger. 1996. Non-uniform ^{15}N labeling of plant parts. Agron. Abstr., Appendix 3. West. Soc. of Crop Sci. Abstr. p. 8.

Samson-Liebeg, S., E.G. Pruessner, R.F. Follett, and J.M. Kimble. 1996. Management effects on surface horizons and soil profile carbon and nitrogen across a precipitation gradient and a temperature gradient. Agron. Abstr. 88:275.

Sharkoff, J.L., J.A. Delgado, R.F. Follett, J.L. and R.R. Riggenbach. 1996. Nitrate leaching assessment of San Luis Valley Water Quality Demonstration Project Sites. 13th Annual Potato/Grain conference. (Monte Vista, Colorado, February 13 - 15) Conference Proceedings pp 9.

Sommerfeld, R.A, W.J. Massman, R.C. Musselman, and A.R. Mosier. 1996. Diffusional flux of CO_2 through snow: Spatial and temporal variability among alpine-subalpine sites. Global Biogeochem. Cycl. 10:473-482.

WATER MANAGEMENT RESEARCH UNIT

Dale F. Heermann, Research Leader
Agricultural Engineering Research Center
Colorado State University
Fort Collins, CO 80523
TEL: (970) 491-8511
FAX: (970 491-8247)

INTERNET: dale@lily.aerc.colostate.edu

TABLE OF CONTENTS
WATER MANAGEMENT RESEARCH UNIT

WATER MANAGEMENT RESEARCH UNIT

CRIS PROJECTS:

5402-12130-005-00D	Water and nitrogen management to protect ground water quality
5402-12130-005-01S	Water and nitrogen management to protect ground water quality
5402-13000-006-00D	Precision farming to protect water quality, conserve resources, with improved irrigation technology
5402-13000-006-01S	Precision farming to protect water quality and conserve resources
5402-13000-006-03T	Improved irrigation management
5402-13000-006-06T	On-site interactive model for irrigation load management
5402-13000-006-08T	Protecting water quality by scouting weed populations for efficient weed management

MISSION STATEMENT

Research emphasis is to integrate applied and basic principles to develop improved water, chemical, and alternative weed management systems and irrigation system designs. Improvements are directed toward sustainable, environmentally sound and efficient systems based on soil, water, fertility, energy, and weed ecology principles. This encompasses understanding physical and biological phenomena and developing computer simulation models and precision farming systems to transfer new technologies to producers, consultants, action agencies, industry, and scientists.

TECHNOLOGY TRANSFER - 1996

WATER MANAGEMENT RESEARCH UNIT

1. Bausch is a member of a standing ASAE subcommittee to develop measurement and reporting practices for automated agricultural weather stations. Development of these guidelines has broad support and participation by individuals from several professional societies and USDA action agencies.

2. Bausch and Heermann are involved in a CRADA with LiCor, Inc. to evaluate their radiometers for real-time sensing onboard a linear move or center pivot sprinkler.

3. Bausch participated in the Central Plains Irrigation Short Course held in Burlington, CO; he coordinated the session "Automation and Remote Sensing - Equipment and Application Benefits" and presented information on use of remote sensing technology in irrigated agriculture.

4. Bausch was program chair for the International Conference on Evapotranspiration and Irrigation Scheduling which was held in conjunction with IA's Annual International Irrigation Exposition in San Antonio, TX. 181 technical papers were presented; 51% were by US authors and 49% were by authors from 39 other countries.

5. Buchleiter provided technical support to several Cooperative Extension agents, Natural Resource Conservation Service field offices, and individual farmers who are publishing crop water use amounts and doing on-farm irrigation scheduling.

6. Buchleiter gave a presentation on "Automation in Irrigation" at the Central Plains Irrigation Shortcource in Burlington, CO.

7. Buchleiter and Heermann participated in the three state Central Plains Irrigation Short Course held in Burlington, Colorado, making presentations

8. Duke worked with CSU Extension and Colorado Climate Center to make data from the Colorado Ag Meteorologic Network, including crop water use estimates, available over the internet and by direct satellite delivery to farmer subscribers.

9. Duke was invited to participate in an Ogallala aquifer workshop at Sterling, CO attended by 300 farmers, business people, and local government officials.

10. Heermann, Buchleiter and Duke are involved in a CRADA with Valmont Industries to extend the capabilities of base station software for monitor and control and to interface and test an independent low-volume chemical application system.

11. Heermann and Stetson (Lincoln, NE) are involved in a CRADA with Electric Power Research Institute to study prediction of peak irrigation electrical loads.

12. Heermann made a presentation at the Precision Decisions 96 Site Specific Farming Conference for farmers in Omaha, NE answering the question "GPS/GIS - The next phase in Precision for Pivot Irrigation?"

13. Heermann presented the latest in center pivot technology to a group of farmers for the MONDAK Economic Development seminar at Williston, ND.

14. Heermann made a presentation on forecasting irrigation peak electrical loads to a planning session of the Nebraska Inter-Industry Electrical Council.

15. The scientists organized and participated in several farmer and researcher oriented meetings to seek input for coordinated, relevant research programs in precision farming and have developed a multidisciplinary team of engineers, agronomists, entomologists, pathologists, economists, statisticians, and weed scientists to take a systems engineering approach to studying the impact of variability on crop yield.

SYSTEMS APPROACH TO MULTIDISCIPLINARY RESEARCH FOR PRECISION FARMING

G.W. Buchleiter, D.F. Heermann, H.R. Duke, W. C. Bausch, R.E. Smith, L. Wiles, D. Westfall[1], P. Westra[1], F. Peairs[1], and B. Bosley[1]

PROBLEM: Current research in precision farming (PF) has focused on rainfed agriculture in correlating the spatial variability of a few major crop production factors with measured yield variability. Many times yield variabilities in subsequent years are unexplained by the prediction model developed from the initial data. This suggests that the prediction model either fails to include all of the major factors affecting yield and/or does not adequately represent the major interactions between the various factors. A well coordinated, multidisciplinary approach is necessary to better understand the causes of yield variability for corn in a sprinkler irrigated environment. A more complete understanding of the various interactions between the crop production factors is needed to assist growers in assessing the economic feasibility of PF as well as more efficient management of the subareas within a field if PF is implemented.

APPROACH: About 25 ARS and university researchers interested in the impacts of water, nutrients, water quality, weeds, insects, and diseases on corn yield as well as the technologies to collect and analyze data for PF, have organized into a PF research interest group. Our goal is to select several fields with significant amounts of variability and do two or more years of intensive, coordinated data collection and analyses, to better understand the complex interactions between the various crop production factors before applying and evaluating any PF practices. Because different sampling strategies and analytical methods are used in the various scientific disciplines, an increased awareness of research methodologies and close coordination of data collection and analyses across disciplines is essential to reach statistically sound and scientifically based conclusions. Written documents are being developed to describe details of the research objectives, the amount and frequency of data to be collected, and the analytical procedures to be used in improving our scientific understanding of the causes of yield variation. A five member management team of researchers from various disciplines directs the research project. To keep data collection efforts manageable and foster cross-disciplinary work within the group, the multi-disciplinary data collection will be on two fields on commercial farms. A project coordinator will use project management techniques to schedule the diverse field data collection and analytical efforts using a single labor pool.

RESULTS: Efforts were focused on identifying the criteria for selecting two field sites where corn will be grown for the next 2 years, and on developing detailed project plans which explain the data collection and analytical approaches that will be used to determine the causes for yield variation.

FUTURE PLANS: Intensive data collection and analyses on variabilities of water, nutrient, weather, weeds, insects, and disease are planned for the next year. Root crops such as sugar beets or onions will be investigated in the future.

---

[1]Departments of Soil and Crop Sci., BioSciences and Pest Mgt (2), Colo. State Univ, and CSU Extension, Morgan County.

PLANT NITROGEN STATUS ESTIMATED FROM CANOPY REFLECTANCE

W. C. Bausch and H. R. Duke

PROBLEM: Over fertilization and /or excessive leaching of nitrogen (N) caused by inopportune rains or overirrigation have been identified as major contributors to excessive levels of nitrogen in the water supplies of many irrigated areas. Applying small amounts of nitrogen as needed by the corn plants during the growing season can reduce potential leaching of nitrogen. Currently, determining the timing and amount of nitrogen to apply, requires laborious and time consuming sampling of individual plants. Widespread adoption of this management practice requires a more rapid and economical method of determining when and how much nitrogen to apply.

APPROACH: The current methodology for measuring the nitrogen status of plants is to take leaf chlorophyll measurements with a SPAD meter. The chlorophyll concentration that is affected by the nitrogen status of the leaves, is also well correlated with leaf reflectance. Remote sensing which measures reflectance, is used to sample an area with many plants and can rapidly assess the spatial variability within a field. Radiometers mounted on a GPS equipped, high clearance tractor are positioned perpendicular and at an oblique angle to the crop surface. Incoming radiation and reflected radiation in the green (G), red (R), and near infrared (NIR) wavebands are measured over a reference area that is not N deficient and over plots with different amounts of applied nitrogen. A N Reflectance Index (NRI) defined as the ratio of the NIR/G at the sample location in the field to the NIR/G of the reference area, is computed for all of the sample locations. Leaf chlorophyll concentrations and the nitrogen content of plants are measured throughout the growing season and correlated with the NRI data. A geographical information system, ARC/INFO, uses these correlations and the reflectance data to create maps of plant N status.

RESULTS: Soil background greatly influenced the reflectance data obtained perpendicular to the crop surface during early vegetative growth, resulting in a poor correlation between NRI and leaf chlorophyll measurements. Measurements with a radiometer positioned obliquely at 15° below the horizontal, 1 m above the crop surface, and perpendicular to the crop row minimized soil reflectance. The plant N status of corn can be estimated at the V9 growth stage with assurance and perhaps as early as V7. The oblique view is recommended throughout the vegetative growth period because the soil background influence is removed. At and after the VT growth stage, the perpendicular view is recommended because the corn tassel overwhelms canopy reflectance at the oblique view. The NRI provides a rapid assessment of N sufficiency that may be superior to the N Sufficiency Index calculated from SPAD data because a plant community is monitored instead of single points on single leaves. Plant N status maps were created using inverse distance weighted interpolation of reflectance data. Nitrogen was applied "as needed" and "where needed" by the crop.

FUTURE PLANS: Data collection will continue at ARDEC under the linear-move sprinkler in 1997. The "spoon-fed" N plots will be fertilized based on the NRI. Studies using the established N fertilizer plots at ARDEC will be continued to further develop relationships between canopy reflectance and plant N status. Canopy reflectance and canopy temperature data will be acquired in two commercial corn fields (Wiggins site) to evaluate plant growth and plant stress effects on yield.

DESIGN AND DEVELOPMENT OF SOFTWARE FOR COMPUTERIZED MONITOR AND CONTROL EQUIPMENT FOR SELF-PROPELLED SPRINKLERS

G.W. Buchleiter, D.F. Heermann, R. Unruh[2], D. Mack[2]

PROBLEM: Growers and researchers both recognize there is significant spatial variability of crop yield within a field. It is hypothesized that overall field yields can be significantly increased by precision farming (PF) with more intensive management and more efficient application of fertilizers, herbicides, pesticides, and irrigation to account for spatial and temporal variabilities within a field. Self propelled sprinklers equipped with variable chemical application systems can apply variable rate chemicals throughout the growing season. Growers are demanding simplified user interfaces to access collected data and to monitor and control multiple systems from a single microcomputer.

APPROACH: Researchers are interested in improving the speed and effectiveness of implementing research findings about improved irrigation management and PF practices on commercial farms. Irrigation equipment manufacturers recognize the value of additional benefits from improved irrigation management that their product can provide to their customers. A cooperative research and development agreement (CRADA) exists between USDA-ARS and Valmont Industries, a major center pivot manufacturer, to aid technology transfer. Software programming is done jointly so researchers know how to access data collected by a monitor and control system for use in decision support programs. User interfaces will be developed for central microcomputers linked to multiple self-propelled sprinkler irrigation systems, to provide variable application of water and chemicals and to effectively and economically deliver precision farming technology under irrigated conditions. Nondifferential GPS units will be explored for determining the position of linear move systems.

RESULTS: Additional capabilities for operation, programming, and determination of field position of the linear move system were integrated with the commercially available WINDOWS version of the base station software marketed by Valmont. Although software testing in the lab showed no problems, field testing of the software indicated recurring communication problems that were eventually traced to the specific timing delays of queries and responses of the field radios. Field testing of the monitor and control system software at ARDEC was continued using spread spectrum radios. Testing of a system that uses an inexpensive GPS receiver and intermediate tower movement time to provide the location of a linear move machine was continued.Work is continuing on a WINDOWS based irrigation scheduling program having graphical input and output capabilities as well as the ability to access irrigation dates and amounts from the database of the monitor and control system.

FUTURE PLANS: Development of prototype graphical programming features of variable water and chemical application will be continued with field testing and evaluation. Software development for automatically translating mapping information to the necessary operational controls on the computerized panel for variable rate application is planned.

REAL-TIME MANAGEMENT OF IRRIGATION SYSTEMS

---

[2] Valmont Industries, Inc., Valley, NE.

FOR IRRIGATION WATER QUALITY

H. R. Duke, G.W. Buchleiter, W.C. Bausch, D.F. Heermann, G.E. Cardon[3]

PROBLEM: Previous studies of crop production and environmental degradation resulting from variability has concentrated on spatial variability, with little attention to temporal variability. Climatic variations and pest outbreaks require timely management decisions to minimize water and chemical inputs. Self-propelled sprinklers irrigate about ⅓ the U.S. irrigated acreage and are a unique platform for site specific applications and precise crop management. With appropriate controls and decision making tools, these systems can be managed to account for variation in water, fertilizer, and pesticide needs.

APPROACH: Current research focuses on real-time decisions at the field level rather than on multi-year planning. An integrated system is being developed to: (1)reduce the difficulty of obtaining data, (2) process data quickly, (3) make appropriate recommendations, and (4) implement the producer's decision in a timely manner. Field experiments evaluate the benefit of fertilizer application in response to measured plant needs as effected by water application. Remote sensing is used to develop rapid assessment of fertility and pests. Three nitrogen and two water treatments are imposed on plots under both a linear sprinkler irrigation system and furrow irrigation. Soil water is measured weekly and estimated by meteorologic methods daily. Crop N status is measured weekly with a chlorophyll meter and by remotely sensed reflectance to evaluate spatial and temporal variability. Chlorophyll meter readings trigger weekly N applications as required to meet crop needs.

RESULTS: Plant chlorophyll was measured with a SPAD meter for real-time control of nitrogen application to test plots, and these readings were correlated with remote sensed canopy reflectance. In the 1996 season, plots receiving all N fertilizer at preplant maintained adequate fertility through the season. Spoonfed plots maintained grain yield with nearly 70 kg/ha less total N applied during the growing season. The software allows control patterns to be manually inputted to generate commands to the sprinkler system for implementation.

FUTURE PLANS: The water and nitrogen study will continue under the linear move linear sprinkler for 1 to 2 more years to validate an irrigation and nitrogen management model. Procedures will be developed to incorporate remotely sensed data of crop nitrogen status directly into control algorithms. Annual soil sampling to 3 meters will be used to estimate the N balance on each plot to evaluate the effectiveness of fertility treatments and water management scenarios for efficient crop use of available nitrogen.

---

[3]Soil and Crop Sci. Dept., Colorado State University.

SPATIALLY AND TEMPORALLY VARIED WATER & CHEMICAL APPLICATION

H.R. Duke, G.W. Buchleiter, D.F. Heermann, W.C. Bausch, J.A. Chapman[4], R.R. Unruh[4]

PROBLEM: Producers rapidly embrace technologies which offer potential economic savings and sustained productivity. Development of precision farming technology is being driven by perceived benefits of applying the optimum amount of fertilizer or chemical at the right place and time, with little scientific understanding of how to determine the optimum amounts. Many decisions that are made prior to planting or the last cultivation, do not account for seasonal variation. Soil properties, fertility, weeds, insects, and other pests vary both spatially and temporally within a single field. When chemicals or water are applied uniformly, some areas may receive insufficient application and others more than can be efficiently used. Excess chemical may be leached, volatized, or otherwise lost. There is potential to reduce costs and environmental degradation by applying water and chemicals only when and where needed.

APPROACH: Center pivot and linear move irrigation systems are used on 1/3 of the U.S. irrigated acreage and provide a ready mechanism to transport both the water application system and a chemical application system. With appropriate controls, these irrigation systems can also apply water and chemicals in different amounts in different parts of the field as needed. Plots have been established at CSU's ARDEC under a linear-move sprinkler system to apply two water and three fertility treatments with three replications. These random treatments create a spatially variable pattern of both water and fertilizer application. Spatial response to variably applied fertilizer nitrogen (N) is measured throughout the season. Sprinkler control systems are being modified to determine field position and apply both water and chemicals to segments of the field as needed using the irrigation system. A pulsing method for applying variable amounts of water is being tested. Low cost devices are being developed and evaluated for mounting on the sprinkler system to variably apply chemicals.

RESULTS: The soils in the study area appear uniform but available N varies widely. Even though preplant and sidedressed treatments were fertilized to the same N level and grain yields were equal, excess irrigation resulted in 33 kg/ha less N remaining in the soil profile at the end of the season. This indicates the importance of applying the appropriate amount of water and N. Sprinkler controls and software have been modified to determine the field position and to implement variable water and chemical application under the linear move sprinkler. Water application has been reliably controlled by pulsing sprinkler heads for three seasons, with uniformities of 90% measured. A unique, low cost pulsed chemical application system has been developed, fabricated, and installed on the sprinkler for field testing in 1997.

FUTURE PLANS: Water and fertility treatments will continue on the same plots under the linear move sprinkler for 1 to 2 years to evaluate variable application equipment and controls. The variable rate chemical application system will be evaluated for precision variable fertilizer and herbicide applications. The pulsing of water for variable water application will continue and the use of position sensed by GPS will be evaluated for position control of variable rates.

---

[4]Valmont Industries, Inc., Valley, NE.

ON SITE INTERACTIVE MODEL FOR IRRIGATION MANAGEMENT

D.F. Heermann, L.E. Stetson[5], and G.W. Buchleiter

PROBLEM: Irrigation pumping is concentrated during a three- to five- month period during the summer for much of the pump-irrigated areas of the U.S. Electric powered pumping increases the peak demands of the electric utilities serving these irrigation loads, requiring costly investments in generation and transmission facilities that are severely underutilized during the non-peak use periods. Since revenues from irrigation pumping are a significant part of the annual revenue for some utilities and do contribute to the economies of communities in irrigated areas, it is desirable to keep power affordable so irrigation remains profitable. Many retail power suppliers have begun irrigation load management programs that reduce their peak demands to either reduce or avoid increases in demand charges from their wholesale supplier. The need is to develop the load control technology that allows power suppliers to generate the needed revenue while providing sufficient electricity at a cost that allows sustainable and profitable irrigation.

APPROACH: Water management research has shown that crop water consumption can be calculated and the results used to schedule irrigation systems for optimum water application. This irrigation scheduling can result in more irrigation systems operating simultaneously which could increase peak power demands. A model for predicting irrigation demands of a retail power supplier will be integrated with existing ARS programs for predicting crop water needs to develop modules for an on-site interactive program to predict daily electric loads caused by irrigation. The perceived needs of irrigators will be compared with actual water needs of the crops to determine the potential reductions in demand. GIS systems will be explored as a technology for delivering a spatially integrated model in a user friendly package. Other models, techniques, or equipment will be evaluated for use or incorporation by modules into the demand prediction program.

RESULTS: A customer focus group made up of Tri-State G & T technical representatives and most REA managers and technical specialists with significant irrigation loads in eastern Colorado and western Nebraska provided input on their needs for forecasting electrical loads. Several cooperatives were either considering or are starting load control programs for irrigation loads. They stated that their need is for short term forecasting of irrigation loads with emphasis on the shoulder months of June and September. Accurate forecasts of electrical demand for the next couple of days would be valuable information to minimize the amount of load controlled and to maximize the benefit of their load control program. They provided data which included billing point demand and total kWh delivered. A time series analysis of the demand data for the years 1992 -1995 is being conducted.

FUTURE PLANS: Daily weather data will be collected to assess its potential for predicting peak demands. A time series model that describes the peak demands of a retail power supplier will be developed. Three scenarios for predicting loads will be: (1) short term forecasting based only on previous demand data, (2) extended forecasting by adding climatic data to demand data, and (3) as needed explore the benefit of including distributed connected load and crop water demand.

---

[5]USDA-ARS, Lincoln, NE.

DEVELOP AN EVALUATION MODEL FOR PERFORMANCE OF CENTER PIVOT SYSTEMS

D.F. Heermann, H.R. Duke, T. Spofford[6] and K. Admire[6]

PROBLEM: Center pivot irrigation systems now irrigate approximately 25% of the total irrigated area in the United States. Based on center pivot manufacturers' sales, the percentage of the irrigated area under center pivots will increase as farmers convert to sprinklers to reduce labor requirements and to irrigate land not suitable to surface methods. Improved sprinkler uniformity is needed to reduce overirrigation and the resulting negative environmental impact on water quality. The Natural Resource Conservation Service (NRCS) is expending considerable effort in collecting field data for evaluating and recommending improvements to sprinkler systems. A computer simulation model of center pivots could decrease the effort to evaluate these systems by calculating applied depths based on the sprinkler hydraulics rather than collecting catch can data. Existing system uniformity and uniformity of system modifications can be evaluated. Currently, a thorough understanding of model is required to use this model reliably. A user friendly interface is needed to enable non-technical personnel to enter the necessary data and interpret the output correctly.

APPROACH: A user friendly model will be developed for use by NRCS technicians and engineers. The model will provide for the entry of field catch can data as is now often collected for use in determining the irrigation uniformity. A pump test and inventory of the sprinkler heads, spacing, and pipe sizes of the system can serve as input to the model and provide an alternative way of evaluating the system. The adoption of low pressure systems requires an increased number of catch cans for an appropriate evaluation. This also makes it important to study the effect of start-stop of the towers which can reduce the uniformity. The first effort will be to investigate the errors introduced in the evaluation process when assuming the system is a continuous move without the start-stop of towers. The current integration requires extensive computation and simplifying techniques will be studied.

RESULTS: A user friendly model for use in Windows on personal computers has been written. A graphical interface is developed to more readily portray the information needed as the program is being used by non expert users. The data required for the simulation includes: pipe sizes, pump curve, sprinkler head spacing, sprinkler type, nozzle sizes, pattern shape, discharge coefficients, pressure regulators, and desired operating speeds.

FUTURE PLANS: The model for continuous move systems will be distributed to selected users for the evaluation of the user friendly aspects of the graphical interface for both input and output. Simulation models will be developed to study different techniques for integrating the application depth of the moving system. The intent is to add an analysis phase to the evaluation that provides specific recommendations for the irrigator when making modifications and for use in scheduling irrigations. A demonstration of the model to the NRCS has been scheduled. The model will be expanded for estimating the uniformity of application with pulsing heads.

---

[6] Natural Resources Conservation Service,Portland, OR and Dexter, MO, USDA.

SURFACE WATER REDISTRIBUTION UNDER MOVING SPRINKLERS

R.E. Smith, D.F. Heermann, P. Luz[7], N.F. Stevens, and K. Stahl

PROBLEM: Sprinkler irrigation systems, especially high volume, low energy types, always have the possibility of applying water at a higher rate than the local infiltration capacity of the soil. Center pivot systems are designed to apply the same depth along the lateral, so the rate varies with distance from the pivot. Additional complications are brought in by variations in topography and soil type. Runoff at any location can redistribute and adversely affect the plant water availability and crop yield. Study of this problem requires the integration of spatial soil and slope information with simulation of time and space variation in application rates. A physically realistic description of infiltration and water movement along furrows is also needed. There is no existing simulation tool with these capabilities, and such tools are potentially useful in both design and analysis.

APPROACH: Progress has been made in simulating spatial distribution of application rates from moving center pivot systems. A GIS approach is being developed which will be able to integrate maps of soil properties, local surface slope and furrow direction, and time-varying maps of sprinkler rates and water depths, to simulate the evolution of applied water depths and water translocations. A separate study is looking at strategies for minimizing runoff at a point for various sprinkler head distributions using an approximate infiltration model which responds properly to changes in application intensity.

RESULTS: The GRASS raster-based GIS system is being thoroughly evaluated as a candidate with which to build the center pivot simulation system (CPSS). Another candidate is the relatively new ARCVIEW pc-based GIS software.

FUTURE PLANS: A basic prototype GIS structure will be constructed to integrate dynamic maps of application rates with maps of soil properties, topography, and dynamic maps of surface and soil water conditions. This exercise will allow evaluation of the interactions of this information and the method of finite difference simulation within the GIS structure, making calculations along furrow directions.

---

[7] INIA, Oeiras, Portugal

WATER MANAGEMENT WITH SPATIAL AND TEMPORAL VARIABILITY

D.F. Heermann, M.J. Paulson[8], G.W. Buchleiter and W.C. Bausch

PROBLEM: Production agriculture has become concerned about its impact on the environment. The degradation of surface and ground water quality is often associated with non-point source pollution from farm operations. The blanket application of water and chemicals over large fields may result in excessive application of chemicals. In contrast, variable-rate technology allows water and chemicals to be applied specifically where they are needed, which should reduce adverse environmental impacts. To apply variable-rate technology in irrigated agriculture, assessment and characterization of spatial variability is essential. Geographical information systems (GIS) used with global positioning systems (GPS) are tools to collect, map and analyze the variability of soil and crop characteristics over space and time. Although such techniques can lead to a better understanding of cause-and-effect and more effective variable-rate treatment, relatively little research has been conducted in this area.

APPROACH: Geo-referenced data will be collected at research plots under surge and linear-move irrigation and at fields under center-pivot irrigation. This topographic, boundary, water, soil, and crop data will be put into ArcInfo GIS for UNIX and/or ArcView 3.0 GIS for PC for spatial analysis and modeling. GPS will be used to spatially position sampled data to interpolate continuous maps characterizing changes in crop growth and yield factors throughout the season. Aerial photographs from field overflights will provide an additional layer of information about crop status periodically. The GIS will be developed into a menu-driven spatial decision support system (SDSS) to allow scientists to rapidly assess spatial variability and relationships among crop growth factors over time.

RESULTS: A topographic survey of the research plots was conducted in June 1996 and a survey of the fields under center-pivot irrigation is scheduled for March 1997. Originally, the ArcInfo menu system could convert GPS data to attributed ArcInfo maps, convert the maps from geographical coordinates to a variety of planar projections, and develop simple map layouts. Last year, the ArcInfo menu-system for data processing was further developed to include data screening, calculation of vegetative indices, a variety of data interpolation and assessment techniques, exploratory analysis, mapping and visualization in ArcView, and metadata creation.

FUTURE PLANS: Spatial information derived from the original data will be used to send variable-rate water and chemical application instructions to the linear-move sprinkler irrigation system. This will require mapping the desired applications into the control language of the sprinkler. A GIS-based irrigation scheduling program should be able to use the spatial information and allocate the water. The ArcInfo menu-system is being generalized to allow for more variables controlling crop water needs to be considered in developing the variable-rate treatments.

---

[8] Department of Horticulture, Colorado State University

MEASURING AND CHARACTERIZING SPATIALLY DISTRIBUTED SOIL HYDRAULIC PROPERTIES

R.E. Smith and N.F. Stevens

PROBLEM: Soil water movement and transport can be simulated if the local soil hydraulic properties are known. These properties vary considerable across a field, even for visually uniform soils, and this variation needs to be characterized to make intelligent management decisions. Current field techniques for measuring soil hydraulic properties are much too time-consuming to allow enough samples to be taken over a field unit to adequately characterize spatial properties. Thus there is little data available of the spatial stochastic structure of soil variations. Much more simple and rapid measurement methods are needed for this purpose. With such tools the spatial characteristics of soil properties can be studied and better strategies for precision agriculture can be developed.

APPROACH: A double-ring disk permeameter was developed and studied as a means to better characterize asymptotic soil hydraulic conductivity, by defining a center area in which the flow is essentially one-dimensional. Numerical simulation may be used as well as field studies to help evaluate the applicability of any measurement device. A much simpler method is proposed to allow measurement of surface soil sorptivity with a test of only a few minutes duration, by measuring accurately the infiltration time of a known depth of water. With this device, measurements will be practical on the order of a hundred points to characterize the spatial distribution of soil properties.

RESULTS: Most permeameter tests assume the infiltration rate at the end of the test is approximately equal to the saturated hydraulic conductivity. This assumption may be seriously in error. The permeameter study revealed a means to use tests of reasonable length (on the order of an hour) and extrapolate to estimate the final infiltration rate much more accurately. A simple small ring has been designed which will be able to make repetitive measurements to characterize spatial distributions.

FUTURE PLANS: The simple sorptimeter design will be tested in the field, and if feasible, will be used to collect large numbers of spatial data for evaluation.

DEVELOPMENT AND APPLICATION OF A DYNAMIC EROSION MODEL

R.E. Smith, D.C. Goodrich[9] and J.N. Quinton[10]

PROBLEM: Whenever there is water running on the soil surface erosion may occur. In addition, when the water is produced by excess rainfall or sprinkler irrigation, the splash energy will exacerbate the erosion, resulting in loss of topsoil and nutrients, and often pollution of receiving waters. This is a complex and difficult process to predict or simulate, and almost all current models simplify and lump the process, or use regression to make long term estimates. To improve our understanding and predictive ability, we need to understand the erosion process in its full dynamic, spatially variable condition.

APPROACH: Our approach is to consider erosion as a transport process intimately linked with the dynamics of water flowing on the surface, and with the energy of the rain or sprinkler rate. The convective transport of soil material must be linked with expressions for local erosion and deposition rates related to rainfall rates and water flow conditions. Existing data for shallow water transport capacities are used to estimate equilibrium transport rates, and these rates are assumed to be the result of continuous, concurrent processes of erosion and deposition. Research will focus on application of this approach in both watershed runoff and irrigated agricultural conditions.

RESULTS: Several physical process models using physically related parameters are incorporated in both the EUROSEM and KINEROS2 simulation models. Data from a variety of shallow water flow flume experiments are being studied to evaluate several existing sediment transport equations for shallow flow applicability. Most existing equations were developed in much deeper flow studies, and do not match the flume data very well. The use of polyacrylimide additive to minimize sediment loss in furrow irrigation was studied during summer 1996, indicating that the movement of fine and suspended material is reduced, but that aggregates and larger particles continue to move as bed load.

FUTURE PLANS: KINEROS2 is in the final steps of programming, and much of it has been tested on selected users. The documentation is planned to be made available electronically, with limited numbers of printed versions. Further study on the available data for shallow flow transport capacity is planned, using data already on hand, and graduate research should continue to add to our understanding of transport of mixed particle sizes.

---

[9] ARS Southwest Watershed Research Center, Tucson, AZ.

[10] Silsoe College, Cranfield, Silsoe, England

PUBLICATIONS

Alam, M., Duke, H.R., and Orendorff, W. 1996. ET information use by Colorado farmers. Proc. Intl. Conf. on Evapotranspiration and Irrigation Scheduling, San Antonio, TX.

Bausch, W.C. and Duke, H.R. 1996. Remote sensing of plant nitrogen status in corn. Trans. of the ASAE. 39(5):1869-1875.

Bausch, W.C., Duke, H.R., and Iremonger, C.J. 1996. Assessment of plant nitrogen in irrigated corn. Proc. 3rd Intern. Conf. On Precision Agric., Minneapolis, MN.

Bausch, W.C. and Bernard, T.M. 1996. Validity of the Watermark sensor as a soil moisture measuring device. Proc. Intl. Conf. on Evapotranspiration and Irrigation Scheduling, San Antonio, TX.

Buchleiter, G.W., D.F. Heermann, R.J. Wenstrom. 1996. Economic analysis of on-farm irrigation scheduling. Proc. of Int. Conf. on Evapotranspiration and Irrigation Scheduling,ASAE. p986-991.

Buchleiter, G.W. 1996. Sprinkler technology. In: 1997 McGraw-Hill Yearbook of Science and Technology. McGraw-Hill Co., New York. pp. 259-260.

Duke, H.R. 1996. COAGMET-Colorado agricultural meteorological network. Proc. Intl. Conf. on Evapotranspiration and Irrigation Scheduling, San Antonio, TX.

Schweizer, E. E., D. W. Lybecker, and L. J. Wiles. Important biological information needed for bioeconomic weed management models. Adv. Soil Sci. (in press) . 1997.

Schweizer, E. E., Westra, P. and D. W. Lybecker. Weed seedbank and floristic composition of annual weeds in corn (*Zea mays*) of Colorado. Weed Sci. (submitted 12/09/96).

Smith, R.E., and Diekkrüger, B. 1996. Effective soil water characteristics and ensemble soil water profiles in heterogeneous soils. Water Resour. Res. 32(7):1993-2002.

Wiles, L.J., King, R.P., Schweizer, E.E., Lybecker, D.W., and Swinton, S.M. 1996. GWM: General Weed Management Model. Agric. Syst. 50:355-376.

Wiles, L. J., D. H. Barlin, E. E. Schweizer, H. R. Duke, and D. E. Whitt. A new soil sampler and elutriator for collecting and extracting weed seeds from soil. Weed Technol. 10:35-41. 1996.

Wiles, L. J. and Schweizer, E. E. Distribution of weed seed and seedling populations in commercial corn fields in Colorado. Weed Sci. Soc. Am. Abstr. 36:82. 1996.

Woolhiser, D.A., Smith, R.E., and Giraldez, J.-V. 1996. Effects of spatial variability of saturated hydraulic conductivity on Hortonian overland flow. Water Resour. Res. 32(3):671-678.